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Report to the Chairman, Subcommittee on Investigations and Oversight, Committee on Science, Space, and Technology, House of Representatives

June 1994

GEOTHERMAL ENERGY

Outlook Limited for Some Uses but Promising for Geothermal Heat Pumps

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GAO

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Resources, Community, and
Economic Development Division

B-255799

June 3, 1994

The Honorable James A. Hayes
Chairman, Subcommittee on Investigations
and Oversight
Committee on Science, Space, and Technology
House of Representatives

Dear Mr. Chairman:

This report discusses the outlook for producing electricity from and directly using geothermal energy. It also discusses barriers to the use of geothermal heat pumps, a promising but relatively unknown technology, and efforts made by industry and government to increase their use. The report recommends that the Secretary of Energy establish a program to promote geothermal heat pumps as a tool for energy-efficient heating and cooling.

As agreed with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to interested congressional committees and subcommittees; individual Members of Congress; the Secretary of Energy; and the Director, Office of Management and Budget. We will also make copies available to others upon request.

This report was prepared under the direction of Victor S. Rezendes, Director, Energy and Science Issues. Please call him at (202) 512-3841 if you or your staff have any questions about this report. Major contributors to this report are listed in appendix V.

Sincerely yours,

Keith O. Fultz

Keith O. Fultz
Assistant Comptroller General

Executive Summary

Purpose

Heat from the earth, or geothermal energy, has the potential to help meet the nation's electricity needs, yet it supplies less than 1 percent of the nation's electricity. The Chairman, Subcommittee on Investigations and Oversight, House Committee on Science, Space, and Technology, asked GAO to review the potential for three uses of geothermal energy—electricity generation, direct-use applications, and geothermal heat pumps—and, for each of these uses, to identify the obstacles to development, the efforts made by industry and government to overcome these obstacles, and the environmental effects.

Background

In several western states, geothermal steam and hot water are currently being used to generate about 2,100 megawatts of electricity, or enough electricity to meet the needs of a city with about 2 million residents. Most of this electricity is produced at The Geysers, a 35-square-mile hydrothermal field in northern California, from which steam, heated to over 300 degrees Fahrenheit, is extracted through about 500 wells, drilled to depths of 6,000 to 10,000 feet.

Lower-temperature heat (below 300 degrees Fahrenheit) from hydrothermal sources can also be used directly to heat buildings and to support aquaculture (fish farming), greenhouse operations, and a variety of industrial processes. At over 300 sites, located primarily in western and midwestern states, geothermal heat is extracted from fluids that are pumped from wells drilled to depths ranging from 500 feet (on average) to over 3,500 feet. This heat, which cannot be economically stored and transported, must be used near its source. The capacity of the direct heat at these sites is equivalent to about 450 megawatts of electricity.

Geothermal heat pumps use the relatively constant temperature of the ground 3 feet or more below the earth's surface. By circulating a fluid through an underground loop of pipe, a heat pump can take advantage of the constant temperature of the subsurface earth (about 40 to 70 degrees Fahrenheit) to provide space conditioning (heating and cooling) for homes and buildings. The current capacity of installed systems is equivalent to about 2,100 megawatts.

The Department of Energy (DOE) funds the research, development, and demonstration of geothermal technologies and disseminates information to utilities, regulators, and others. The Energy Policy Act of 1992 authorized DOE to (1) conduct a 5-year program to promote energy-efficient heating and cooling technologies and (2) cofund the

establishment of 10 regional centers for demonstrating the most efficient heating, cooling, and lighting technologies. DOE's fiscal year 1994 funding for geothermal research and development was about $24 million.

Results in Brief

Growth in the use of geothermal energy to generate electricity will be modest because most of the known economically viable hydrothermal fields are being used and are slowly being depleted. Furthermore, the price of electricity generated from these fields is only marginally competitive with that of electricity derived from other sources. To improve the competitiveness of geothermal power, DOE is supporting industry efforts to extend the life of the hydrothermal fields, explore for new resources, and reduce drilling costs. Although geothermal power production may create some emissions and wastes, it causes fewer, less serious environmental problems than conventional power production.

Geothermal resources suitable for direct-use heating applications offer an environmentally benign resource alternative; however, their potential for growth is poor because applications are limited by the high risk of drilling and high cost of installation, low price of fossil fuels, and lack of information on site-specific geothermal resources located near large population centers.

Geothermal heat pumps are the most energy-efficient means of heating and cooling buildings in most areas of the United States. Their wider use could cut energy costs, conserve fossil fuels, and reduce emissions. However, their use to date has been limited because consumers, contractors, installers, and utilities are unfamiliar with the technology; installation costs are high; and neither DOE nor industry has actively promoted them.

Principal Findings

Growth Potential for Geothermal Electricity Production Is Limited

The generating capacity of geothermal steam and hot water quadrupled from 1980 to 1990 but declined by 22 percent between 1990 and 1993. Although DOE continues to project substantial increases in capacity, industry and utility officials see less opportunity for growth. Most of the large known high-temperature hydrothermal fields are now being tapped, and, under current production conditions, are slowly being depleted. DOE

is supporting industry efforts to sustain productivity by, among other efforts, injecting water into the geothermal reservoirs; however, according to operators and DOE officials, this action will slow but not reverse the depletion. DOE has also demonstrated the technical but not the economic feasibility of extracting geothermal energy from hot dry rock.

Market factors deter the growth of geothermal power production. Many utilities located near geothermal resources do not need additional power capacity, and the low price of natural gas discourages investment in geothermal production. To make geothermal power generation more competitive, the federal government is funding research and development to lower drilling and extraction costs and has established tax credits for geothermal development.

Geothermal power generation offers significant environmental benefits compared with fossil fuel or nuclear power generation. Because it does not entail combustion, it does not produce the emissions that contribute to acid rain, smog, and the greenhouse effect. And when it produces by-products, these by-products—dissolved gases and sludge—are easier to dispose of than nuclear waste.

Economic Considerations Limit Growth Potential of Direct Use

The initial development or start-up cost for finding and drilling productive wells for direct-use applications is a cost risk many operators cannot afford on their own. In the 1980s, the federal government, along with a few western states, primarily California, helped foster the growth and development of direct-use applications by cofunding demonstration projects and by providing financial and technical assistance. For example, a greenhouse located near Salt Lake City, Utah, which had been heated by oil and gas, was retrofitted to use geothermal heat at a cost of $687,000 (with 66 percent funded by the federal government). The greenhouse owner said that if the government had not funded the drilling cost ($416,000), he would not have been likely to pursue the project.

Geothermal direct-use projects offer a sustainable, environmentally benign energy resource. They are often designed as closed circulation systems that do not emit harmful gases or produce solid waste. For open systems, federal and state environmental regulations control the rate at which fluids containing harmful chemicals can be released into surface water.

Geothermal Heat Pumps Show Great Potential

Geothermal heat pumps are the most energy-efficient, environmentally clean, and cost-effective space-conditioning systems for most locations,

according to the Environmental Protection Agency. Despite these advantages, geothermal heat pumps have less than one-half of 1 percent of the space-conditioning market: As of 1992, 150,000 units had been installed. While the greatest activity to date has been in the residential market, commercial and public buildings represent an even bigger market, according to industry officials.

Sales of geothermal heat pumps have lagged because consumers, contractors, and installers are often unfamiliar with the technology; installation costs are high; and utilities with excess generating capacity have little incentive to promote a technology that will reduce energy consumption and profits. While the Energy Policy Act of 1992 authorizes DOE to accelerate the development of technologies that will increase energy efficiency, such as geothermal heat pumps, DOE has done little to support this endeavor. For example, in fiscal year 1993, DOE devoted only $250,000 and assigned one staff member to work part-time on geothermal heat pump initiatives.

Geothermal heat pumps can reduce energy consumption—and corresponding emissions—by as much as 44 percent compared with air source heat pumps and by as much as 72 percent compared with electric resistance heating and standard air-conditioning equipment, according to an Environmental Protection Agency study. GAO estimates that if geothermal heat pumps were installed nationwide, they could save several billion dollars annually in energy costs and substantially reduce pollution.

Recommendation

Because of the significant economic and environmental benefits that geothermal heat pumps may provide, GAO recommends that the Secretary of Energy establish, under DOE's existing authority, a program to promote them as a tool for energy-efficient heating and cooling. Under this program, the Secretary should gather and disseminate information on them; establish, to the extent feasible, regional demonstration centers; and encourage state regulators and utilities to promote them.

Agency Comments

In written comments on a draft of this report, DOE agreed with most of the information and provided clarifications and updates that have been incorporated where appropriate. However, DOE considered the report unduly pessimistic, especially in its discussion of the outlook for generating electricity from geothermal resources, and suggested that evidence had been selected to bolster a particular conclusion. GAO believes

that the report presents a balanced view of the prospects for developing geothermal uses and draws logical conclusions from the best available geological and marketing evidence. This evidence shows that most of the known large fields have already been developed and that operators are extracting energy from them faster than nature can replace it. In addition, the availability of lower-priced fossil fuels limits the potential for geothermal energy production. DOE did not provide GAO with any new evidence to support a more optimistic outlook.

Although DOE did not comment specifically on GAO's recommendation, it noted that the President's Global Climate Change Initiative includes programs that will hasten the spread of geothermal heat pumps. This observation is consistent with the thrust of GAO's recommendation. DOE's comments are summarized in chapter 2 and reproduced in appendix IV, together with GAO's response to the comments.

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Appendixes

Related GAO Products

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Abbreviations

CEC	California Energy Commission
DOE	Department of Energy
EPA	Environmental Protection Agency
GAO	General Accounting Office
GHP	geothermal heat pump
PON	program opportunity notice

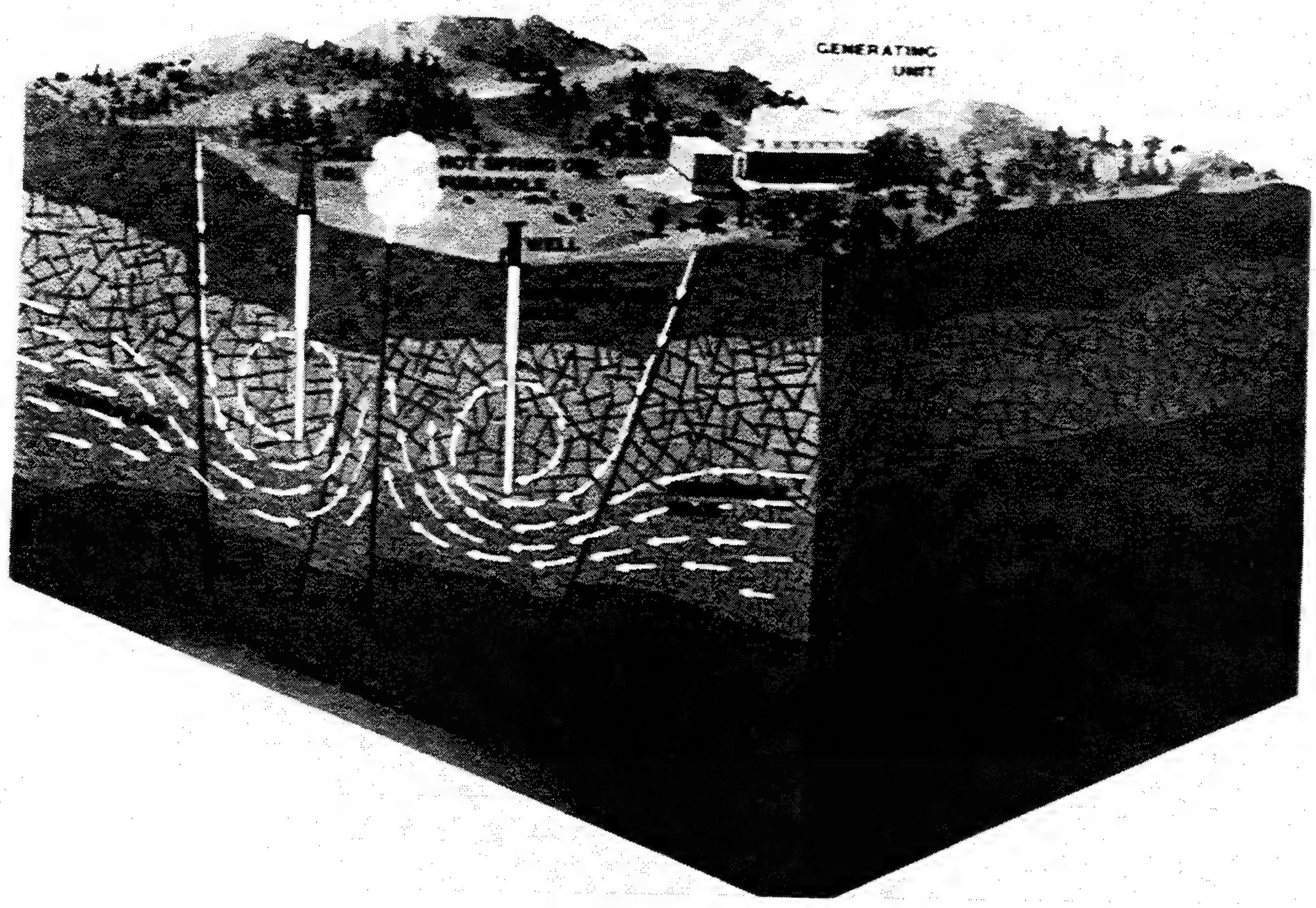
Introduction

Increasing dependence on foreign energy sources, as well as growing awareness of the need to protect the environment, has led the U.S. Department of Energy (DOE) to seek new domestic alternatives to producing energy by burning fossil fuels. Geothermal energy is an alternative that can be used to produce electricity, heat and cool buildings, and provide heat for a variety of commercial and industrial processes.

Generating Electricity From Geothermal Resources

Geothermal energy—or energy from the internal heat of the earth—has been used to produce electricity in the United States since 1960. At discrete sites in several western states, geological processes have created underground reservoirs of steam or hot water at high enough temperatures and shallow enough depths to make electricity production viable. Geothermal developers have drilled wells into these naturally occurring "hydrothermal" resources and used several techniques to convert the heat energy in the steam or hot water into electricity (see fig. 1.1).

Figure 1.1: Cross Section of the Earth Showing the Source of Geothermal Energy



Note: Magma, the molten rock found deep within the earth, conducts heat energy through the solid rock above it. This intense heat then comes into contact with underground water and transforms the water into a geothermal resource.

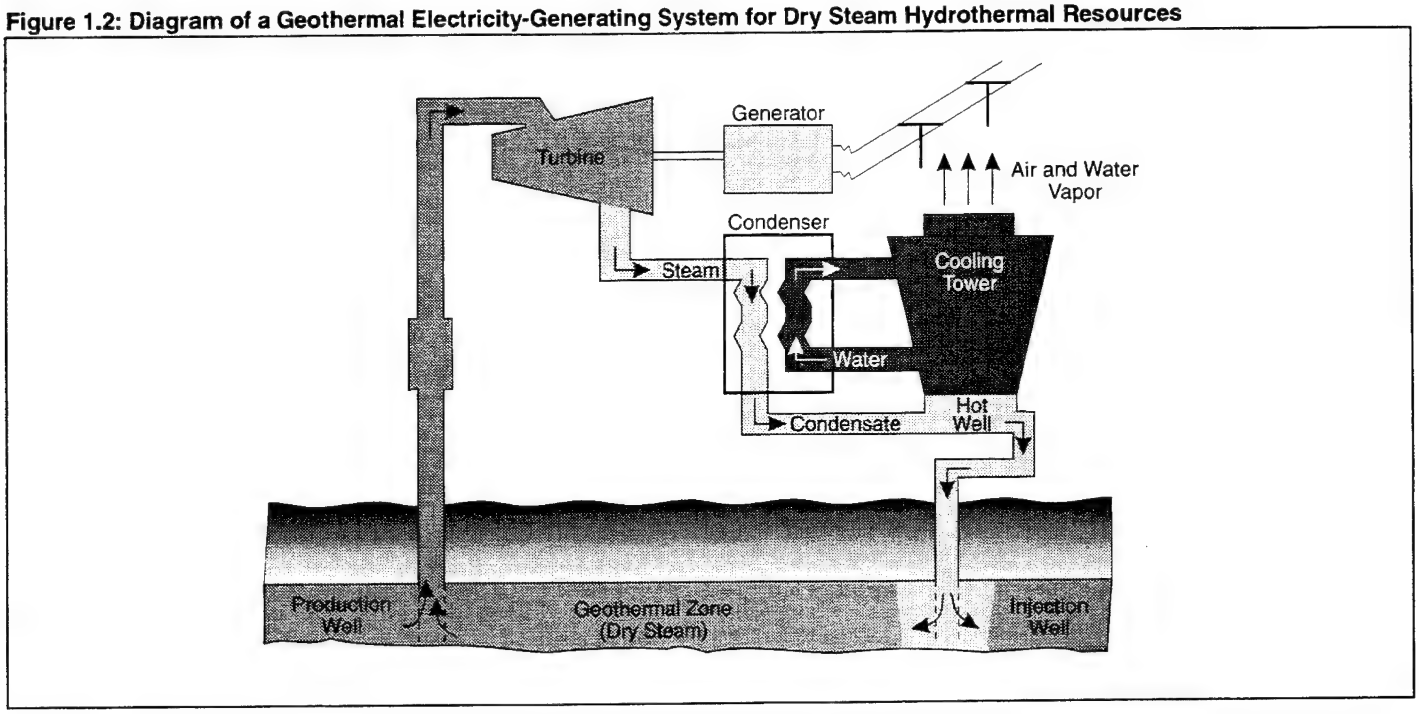
Source: DOE.

Existing Technologies

Most geothermally produced electricity has come from The Geysers, a 35-square-mile hydrothermal field in northern California. At The Geysers, about 500 wells, most of which are 6,000 to 10,000 feet deep, tap into the steam reservoir, whose temperature is over 300 degrees Fahrenheit. The dry steam passes directly from the reservoir to a turbine to produce electricity (see fig.1.2). As the steam passes through the generating system, it cools and condenses. Some of the condensate is released into the

atmosphere in the cooling process, and the rest is injected back into the hydrothermal field. This dry steam technology is the most economic technique for producing electricity from geothermal resources.

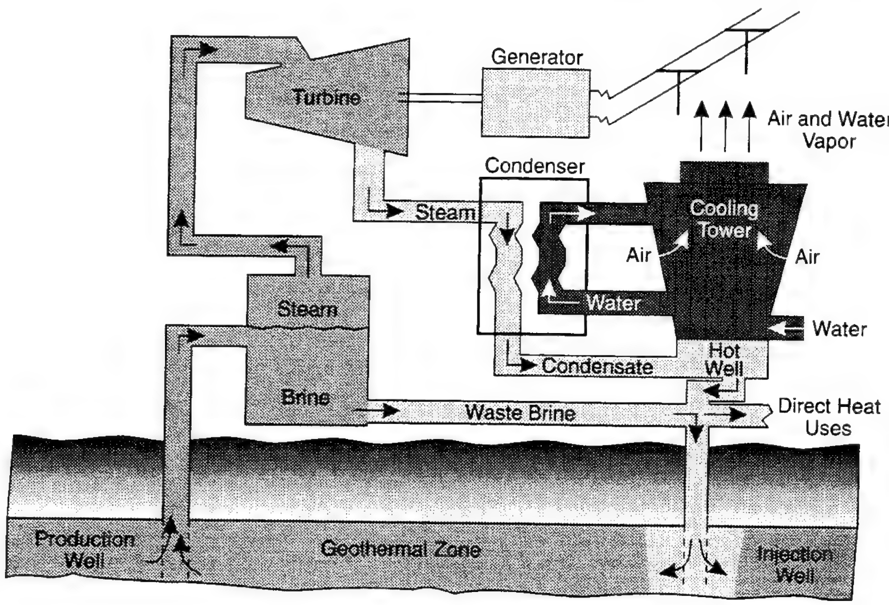
Figure 1.2: Diagram of a Geothermal Electricity-Generating System for Dry Steam Hydrothermal Resources



Source: Petroleum Information Corporation, The Geothermal Resource (A.C. Nielson Co., 1979), p. 40.

Except for the steam-producing Geysers, all other known hydrothermal resources in the United States consist of hot pressurized liquid. If this liquid is hot enough, it can be brought to the surface and converted into steam through a process called "flashing" and passed through a turbine to produce electricity. During the process, some of the steam is released into the atmosphere. Any residual fluids are disposed of or reinjected into the hydrothermal field (see fig. 1.3).

Figure 1.3: Diagram of a Single-Flash Geothermal Electricity-Generating System for Hot Liquid Hydrothermal Resources



Source: Petroleum Information Corporation, The Geothermal Resource (A.C. Nielson Co., 1979), p. 40.

Another technique for generating electricity from fluid reservoirs is the binary cycle system, which uses two closed fluid loops. The first loop contains fluid from the reservoir, which is circulated through a heat exchanger and returned to the reservoir to be reheated. The second loop contains a fluid with a lower boiling point. The secondary fluid is converted by the heat exchanger into vapor, which powers the turbine, condenses, and is then circulated back through the heat exchanger, repeating the process.

Possible Future Technologies

Three other sources may be used to generate geothermal electricity in the future—hot dry rocks, geopressured geothermal resources, and magma. All require further research and development to be used economically.

Hot dry rock technology uses heat from the earth's crust to generate electricity. This technology involves deep drilling; pumping highly

pressurized water into the well to fracture the hot rock and create a reservoir; drilling a second, or production, well into the reservoir; and then pumping pressurized water down into the first well, where it is heated as it flows through the hot rock and back up the production well. DOE has funded a demonstration project in New Mexico to test the technical feasibility of this technology.

Geopressured geothermal resources refer to highly pressurized, hot fluids containing dissolved natural gas. These resources are generally found at depths of between 12,000 and 21,000 feet in the vicinity of the Gulf of Mexico. Magma refers to molten rock at very high temperatures, such as is emitted during volcanic eruptions on the Hawaiian Islands. However, the technology to harness the energy contained in the fluids and molten rock does not currently exist. Since DOE does not believe these resources will be economically developed in the foreseeable future, it has suspended research to develop them.

Using Geothermal Heat Directly

Heat from hydrothermal sources can also be used directly for heating buildings and for a variety of industrial processes. Through a direct-use process, hot fluids are brought to the surface and distributed through a closed circulation loop via pipes to an exchanger that extracts the heat to be used and then reinjects the spent fluids into the water reservoir. The hot fluids can also be used in an open system through which the heat is extracted and then disposed of through surface releases into rivers, lakes, or irrigation systems. For both closed and open systems, the hot fluids are pumped from wells drilled at depths ranging from 500 feet (on average) to over 3,500 feet. Some geothermal wells, however, are free-flowing artesian wells requiring no pumps, but these are relatively rare and are usually located near natural hot springs.

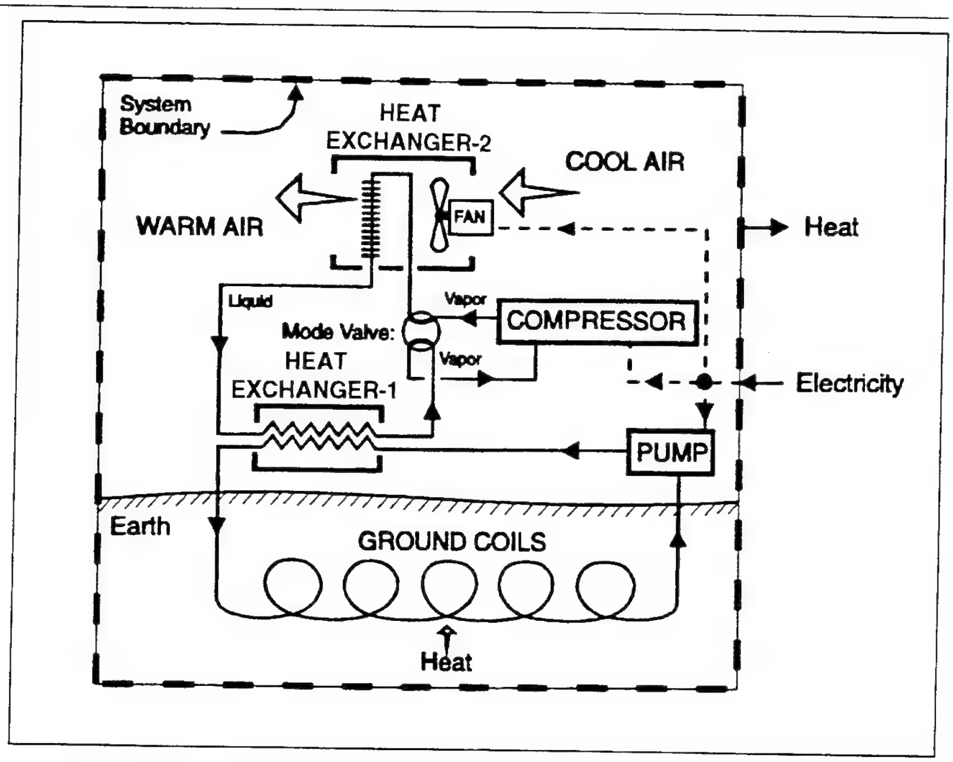
While geothermal heat of all temperatures is suitable for direct-heating applications, the most widely available source is low- to moderate-temperature (below 300 degrees Fahrenheit) hydrothermal fields. Geothermal resources can be used to heat a single structure (space heating) or several buildings (district heating), swimming pools, and spas. Geothermal heat is also used in greenhouses, aquaculture (fish farming), and industrial processes such as dehydrating vegetables, drying grain and lumber, processing pulp and paper, and treating wastewater. The total U.S. capacity for direct use at over 300 sites is approximately 450 thermal megawatts,[1] out of a worldwide total of 11,300 thermal megawatts.

[1]A thermal megawatt is the heat energy equivalent of a megawatt of electricity.

Geothermal Heat Pumps

Geothermal heat pumps (GHP) are devices that take advantage of the relatively constant temperatures immediately beneath the ground's surface to provide heat in winter and air conditioning in the summer. A GHP system consists of two parts—(1) an exchanger (the heat pump unit) for heating and cooling a building and (2) a loop of pipe extending vertically or horizontally beneath the earth's surface (see fig. 1.4).

Figure 1.4: Diagram of a Geothermal Heat Pump



Source: DOE.

In the winter, the fluid pumped through the pipe (typically a solution of water and antifreeze) extracts heat from the earth. The heat pump unit transfers the heat to a refrigerant, which boils at a low temperature. The heat pump then compresses the gas, increasing the temperature of the gas. The high-temperature gas is then pumped to the condenser, where it gives up heat when a fan blows air across the condenser coils. As the gas loses heat, it changes back into a hot liquid. Then it passes through an expansion valve that further reduces temperature and pressure. The

low-temperature, low-pressure liquid is pumped back to the evaporator, and the process begins again.

In the summer, the system works in reverse. The heat from the building is pulled across the condenser coils, and the liquid refrigerant evaporates. The compressor pumps the heated gas to the evaporator, heat flows from the refrigerant to the cooler water, and the refrigerant condenses. Then the warmed water is pumped from the heat pump through the ground loop, where it gives up its heat to the cooler earth.

The Federal Geothermal Energy Program

Federal involvement in the geothermal industry began with the passage of the Geothermal Steam Act of 1970, which authorized the Department of the Interior to lease geothermal resources on federal lands. The Arab oil embargo of 1973 sparked the establishment of a federal energy program to promote the development of alternative energy sources. The Federal Geothermal Energy Research, Development, and Demonstration Act of 1974 provided for the research, development, and demonstration of geothermal energy technologies and established a loan guaranty program for financing the development of geothermal energy.

Passage of the Public Utility Regulatory Policies Act of 1978, as amended, authorized the Federal Energy Regulatory Commission to require utilities to offer to buy electrical power from geothermal producers. Implementation of this law in California led to the rapid expansion of geothermal power production in the 1980s because the state regulators established high enough prices to attract investors and developers.

Research and Development

DOE is responsible for overseeing the federal research and development of a variety of electricity supply technologies, including those based on renewable (including geothermal), nuclear, and fossil energy sources. Program managers in DOE's Geothermal Division within the Office of Energy Efficiency and Renewable Energy oversee groups of renewable energy technology research and development projects, which are carried out by national laboratories, universities, and private industry. DOE's funding for geothermal energy research and development from fiscal year 1975 through fiscal year 1993 amounted to about $1 billion. DOE's fiscal year 1994 budget provides $24 million for geothermal energy research and development.

The Renewable Energy and Energy Efficiency Technology Competitiveness Act of 1989 authorized joint ventures between DOE and the private sector for commercial demonstration projects for energy efficiency and for certain renewable energy technologies. In January 1992 testimony, DOE's Assistant Secretary for Conservation and Renewable Energy noted that such partnerships leverage the impact of federal spending and increase the likelihood that the technologies under development will be commercially adopted.

Energy Policy Act of 1992

The Energy Policy Act of 1992 contained a number of provisions to promote geothermal as well as other alternative energy sources. These provisions

- permanently extended tax credits for investment in geothermal property;
- authorized DOE to undertake a 5-year program to promote the development of energy-efficient heating and cooling technologies and to cofund the establishment of 10 regional demonstration centers to provide information, training, and technical assistance on such technologies; and
- required states to eliminate disincentives for utilities to invest in measures designed to promote energy efficiency and conservation.

Environmental Requirements

Environmental legislation, such as the Clean Air Act and its subsequent amendments, limits major air pollutants from power plants and thus encourages the development of nonpolluting alternative energy resources. Over two-thirds of the electricity generated in the United States is produced by burning fossil fuels, accounting for significant portions of the sulfur dioxide, nitrogen oxide, and carbon dioxide emissions. These emissions contribute to acid rain, urban smog, and global warming.

Objectives, Scope, and Methodology

The Chairman, Subcommittee on Investigations and Oversight, House Committee on Science, Space, and Technology, asked GAO to review the potential for three uses of geothermal energy—electricity generation, direct-use applications, and geothermal heat pumps—and, for each of these uses, to identify the obstacles to development, the efforts made by industry and government to overcome these obstacles, and the environmental effects.

To complete these objectives, we obtained projections of the capacity for geothermal power from DOE and interviewed and obtained information

from government, industry, utility, and research community representatives on geothermal energy development. We interviewed and obtained information from DOE officials in the Geothermal Division, the Office of Buildings Technologies, the Idaho Field Operations Office, the Energy Information Administration, and the Federal Energy Management Program, as well as from officials at DOE laboratories—including the National Renewable Energy Laboratory, Golden, Colorado; the Sandia National Laboratory, Albuquerque, New Mexico; the Los Alamos National Laboratory, Los Alamos, New Mexico; and the Lawrence Berkeley Laboratory, Berkeley, California—and at the Bonneville Power Administration and the Western Area Power Administration. In addition, we contacted officials at the Environmental Protection Agency, the Department of the Interior's Bureau of Land Management, the Department of Defense, the U.S. Geological Survey, and the National Academy of Sciences. At the state and local level, we contacted officials involved in energy and environmental issues in 19 agencies in areas with geothermal activity or potential. Finally, we contacted and obtained information from 21 geothermal businesses and independent power producers, 21 utility companies, 9 energy-related organizations, and 9 universities and research institutes. These agencies and organizations are listed in appendix I.

We also attended DOE's 1993 geothermal program review, at which government and industry speakers presented papers and summaries of the progress made over the past year.

We conducted our work from November 1992 through December 1993 in accordance with generally accepted government auditing standards.

DOE's comments on a draft of this report appear in appendix IV. These comments focus primarily on our discussion in chapter 2 of the prospects for generating electricity from geothermal resources. DOE found our conclusions overly pessimistic and considered our selection of evidence unbalanced. We summarize and respond generally to DOE's comments at the end of chapter 2 and provide specific responses to individual comments at the end of appendix IV.

Obstacles to Producing Electricity From Geothermal Resources

After a decade of high growth, efforts to develop and convert geothermal resources to produce electricity have slowed significantly. Further expansion of geothermal electricity production faces a number of obstacles, including resource limitations, market barriers, and, in some cases, environmental concerns. Although government agencies, utilities, and industry groups are taking measures to minimize the effects of these barriers, growth for geothermal electricity production over the next 20 years is not expected to meet DOE's projections.

Geothermal Electricity Production Provides Dependable Operation and Environmental Benefits

In 1993, about 2,100 megawatts of geothermal electrical power were being generated continuously in the United States—enough power to supply the needs of about 2.2 million people. In terms of operational reliability, geothermal plants are one of the most dependable sources for generating electricity; their on-line performance typically exceeds 90 percent. However, electricity produced from geothermal sources constitutes less than 1 percent of the U.S. electricity supply.

Geothermal power production poses fewer environmental problems than conventional power generation. In the United States, electric utilities account for 70 percent of the sulfur dioxide emissions (the main cause of acid rain); 33 percent of the nitrogen oxide emissions, which contribute to smog; 20 percent of the gases linked to the atmospheric greenhouse effect (mainly carbon dioxide); and 50 percent of all nuclear waste. Using a geothermal plant, which draws and returns hot fluids from underground reservoirs, in place of a fossil fuel or nuclear plant eliminates all or most of these pollutants.

DOE's Projections Are High

The 1980s was a period of rapid growth in the production of geothermal electricity. In 1980, the installed U.S. geothermal electricity capacity was 680 megawatts, almost entirely at The Geysers, a hydrothermal field in northern California. By the end of 1990, about 2,000 megawatts of capacity had been added. This rapid growth was triggered by the California Public Utility Commission's adoption of Standard Offer 4 provisions, which required California's regulated utilities to purchase power from qualified independent geothermal producers at premium prices.[1]

[1]The Standard Offer 4 contracts were part of California's implementation of the Public Utility Regulatory Policies Act of 1978. The contracts provided fixed payment rates for power purchases over a 10-year period. By guaranteeing purchases at a premium price—and thereby providing some certainty in the return on investment—the contracts encouraged independent power producers to develop geothermal generating capability.

Rather than continuing to grow rapidly as it did in the 1980s, net geothermal generating capacity has actually decreased from about 2,700 megawatts in 1990 to about 2,100 megawatts in 1993. While some new capacity has been added, it has not offset declines at The Geysers, the world's largest geothermal field. Nevertheless, as table 2.1 shows, DOE's studies continue to predict substantial growth in the production of geothermal power in the future. These studies, however, do not consider actual and projected production declines. For example, net capacity at The Geysers has declined from a high of about 2,000 megawatts in 1989 to 1,220 megawatts in 1993, and field operators expect it to decline about another 600 megawatts over the next 20 years. According to one DOE official, the agency has not had time to include estimates on the rate of decline in its projections. In December 1993, DOE officials also told us that their projections for geothermal power production may not be realized because demand for new power in the West has lessened and funding for research has been lower than anticipated.

Table 2.1: DOE's Projections of Geothermal Power Capacity

Projections in megawatts

	Year to which projection applies					
Year of study	**1995**	**2000**	**2005**	**2010**	**2020**	**2030**
1990[a]	[b]	3,458	[b]	5,912	8,589	10,596
1990[c]	[b]	5,577	[b]	10,038	16,731	20,077
1991[d]	3,250	6,250	9,650	10,650	19,500	23,400
1992[e]	2,843	[b]	[b]	11,661	[b]	27,442
1993[f]	3,670	5,180	6,850	8,510	[b]	[b]

[a]The Potential of Renewable Energy: An Interlaboratory White Paper, DOE, SERI/TP-260-3674 (Golden, Colo.: Mar. 1990), p. C-7.

[b]The cited DOE study did not include a projection for this year.

[c]Renewable Energy Excursion: Supporting Analysis for the National Energy Strategy, Energy Information Administration, SR/NES/90-04 (Washington, D.C.: Dec. 1990), p. 22.

[d]Annual Energy Outlook 1991, Energy Information Administration, DOE/EIA-0383(91) (Washington, D.C.: 1991), p. 50.

[e]S. Petty, B.J. Livesay, and J. Geyer, Supply of Geothermal Power from Hydrothermal Sources: A Study of the Cost of Power Over Time, prepared for DOE Sandia National Laboratory, 1991, p. 22-3.

[f]Annual Energy Outlook 1993, Energy Information Administration, DOE/EIA-0383(93) (Washington, D.C.: 1993), p. 88.

Furthermore, all the industry, geothermal development, and utility officials we interviewed believe that DOE's estimates are extremely optimistic. For

example, the North American Electric Reliability Council projects a decrease of about 8 percent in actual geothermal power production from 1991 to 2001. And although geothermal developers are predicting future growth in production for the industry, they believe that the projection in DOE's National Energy Strategy of 20,000 megawatts by 2030 is unrealistic. They cited the future price of fossil fuels as a key factor in determining the rate of growth—sharply rising oil and natural gas prices are needed to benefit the geothermal industry. Finally, although utility industry representatives anticipate modest growth in geothermal power capacity—about 530 additional megawatts by the year 2000—this estimate is small compared with the 3,100-megawatt increase over 1993 capacity that DOE projects in its Annual Energy Outlook 1993.

If market conditions for geothermal power improve, expanded production from known geothermal fields in the United States is possible. Idaho National Engineering Laboratory officials estimated the increase at 2,500 megawatts with little or no new exploration. Furthermore, in 1992, the University of Utah Research Institute concluded that the total potential for new geothermal power production in the next 20 years using current technology is 4,800 megawatts—of which 2,650 megawatts would come from known fields and 2,150 megawatts would come from new discoveries.[2]

Resource Barriers Limit Growth

Geothermal electricity production is currently limited to specific sites in a few western states where there is enough steam or pressurized hot water at high enough temperatures and shallow enough depths to be economically viable to develop. Most of the large known fields are now being tapped. Production at such sites is not sustainable because companies seeking to recover the costs of developing a geothermal site extract energy at a faster rate than nature replenishes it. Efforts are under way at The Geysers to slow production declines by injecting water into the underground reservoir. Efforts by DOE to expand the resource base by developing hot dry rock technology have been cut back because funds are limited and most industry officials believe that the technology is not economically viable at this time.

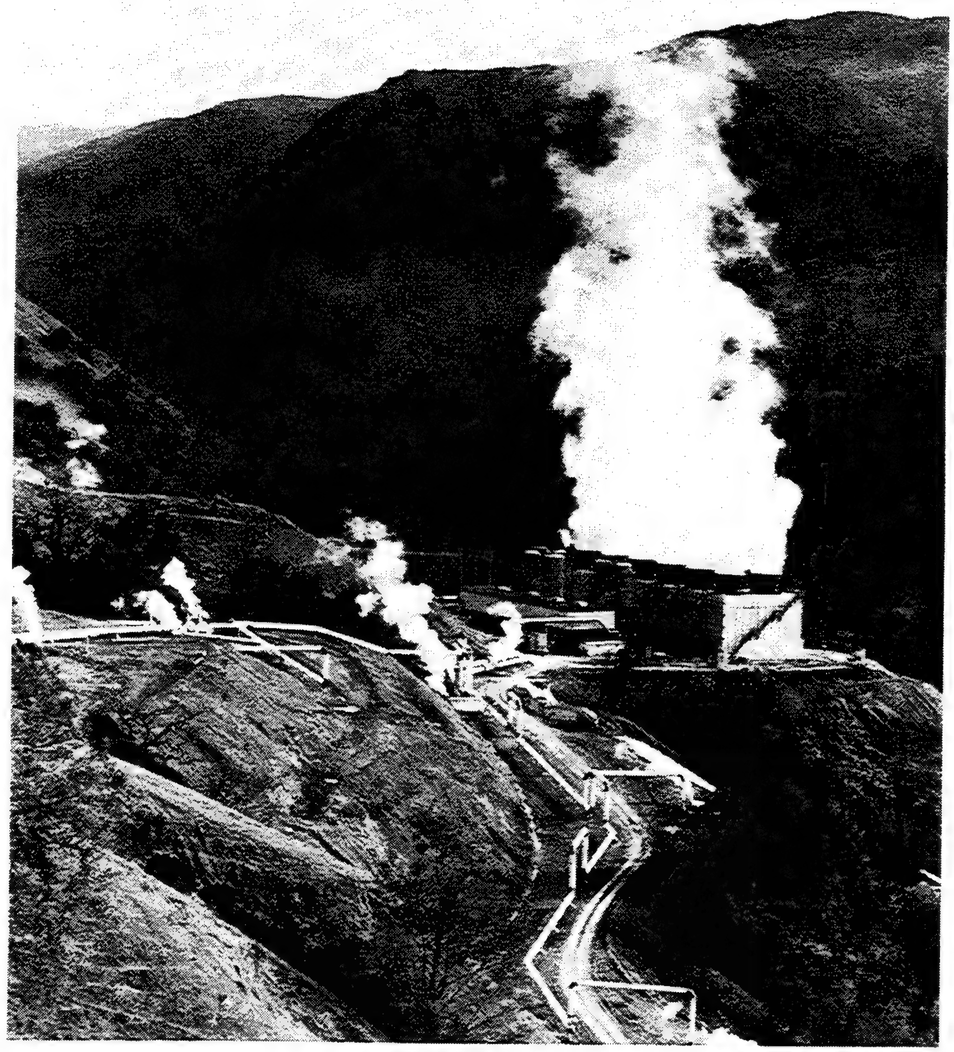
[2]P.M. Wright, "Exploration Potential for New Hydrothermal Resources for Electrical Power Generation in the 48 Contiguous United States," Geothermal Resources Council Bulletin (Feb. 1992), pp. 31-43.

Geothermal Power Production Is Not Sustainable

The generation of electricity from hydrothermal fields cannot be sustained over the long term under current production conditions. To recover the millions of dollars they have invested in developing a geothermal power facility, companies are extracting heat energy from the fields at a faster rate than nature can replenish it. This heat-mining approach depletes the quantity, pressure, and possibly the temperature of the underground reservoir.

For example, at The Geysers (see fig. 2.1) and at the Coso hydrothermal fields in California, an evaporative water cooling process is used to create a vacuum to help pull the steam into the turbine and generate electricity more efficiently. However, this process removes water that could be used to replenish the reservoir. At The Geysers, between 60 and 80 percent of the extracted steam, and at Coso between 30 and 40 percent of the steam, is lost through this process and is thus not available for reinjection to help sustain the fields. In 1988, when production at The Geysers reached its peak, 230 billion pounds of steam were extracted.

Figure 2.1: Generating Units at the Geysers in California



Note: Steam is transported to the generating units through insulated pipes.

Source: DOE.

Strategies Are Being Developed to Prolong the Life of the Geysers

While much of The Geysers' steam has been depleted and there is little natural replenishment, most of the heat in the surrounding rock remains. DOE and the California Energy Commission are currently supporting efforts

by geothermal developers and utilities to find the most effective strategies for prolonging the life of The Geysers.[3] According to DOE and The Geysers' operators, these efforts will slow the decline but will not reverse it.

DOE is funding reservoir modeling and reinjection studies to learn why reinjecting water is more effective at some locations in The Geysers than at others. The Geysers covers a 35-square-mile mountainous area, and reinjecting water has produced varying results. For example, the Northern California Power Agency gets 70 percent of its injected water back as steam; Calpine gets 40 to 45 percent back; and UNOCAL and the Sacramento Municipal Utility District get around 20 percent back.

To decrease the water loss, The Geysers' operators are studying the possibility of installing air-cooled systems in place of water-cooled systems at some of these plants. While this technology would significantly reduce the amount of water lost from the reservoirs (through the water-cooling evaporative process), it has several drawbacks that are being evaluated by the operators. First, air-cooled systems require more flat land than may be available in the mountainous area; second, they are more expensive to build than water-cooled systems; and third, they generate less power than water-cooled systems during the summer months when utilities have a high demand for power.

DOE has also played a pivotal role in a project to build a 26-mile pipeline to bring water from Lake County, California, to The Geysers for injection. DOE provided a $450,000 grant for the feasibility study and environmental impact statement. According to one of The Geysers' operators, the project would not have been considered without federal support because his company initially did not believe it was feasible. The cost of the proposed pipeline project is estimated at $29 million; funding is to come from industry, utilities, and county, state, and federal sources. Officials estimate that the project will increase steam output enough to bolster production capacity by 44 megawatts or more.

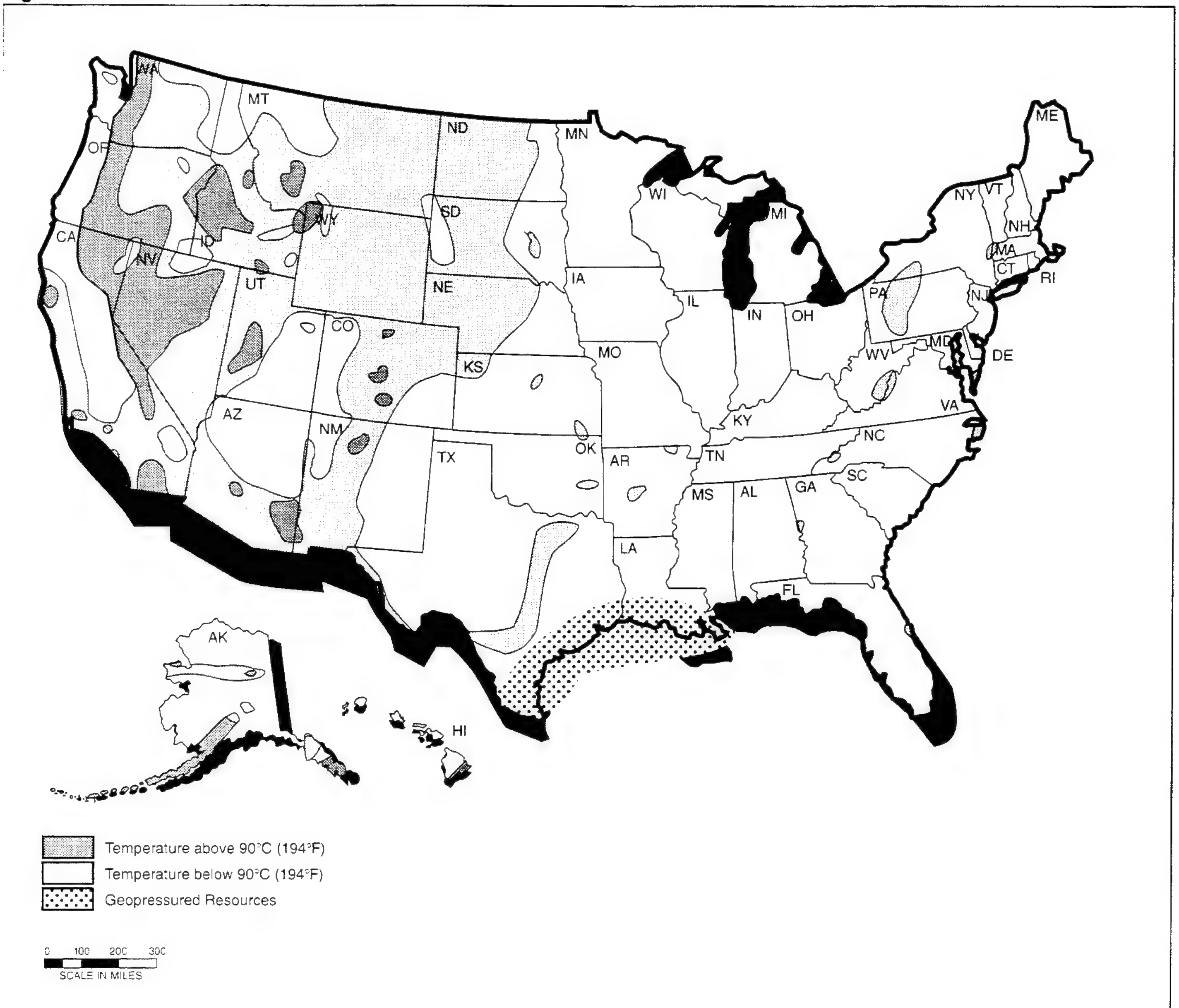
Most of the Large Known Geothermal Fields Are Now Being Used

In 1978, the U.S. Geological Survey completed an assessment of the geothermal resources of the United States (see fig. 2.2). This survey identified specific sites with good potential for geothermal power production. In the 15 years since, very few additional fields of substantial size have been discovered. The only major field not included was Glass

[3]Field developers and plant owners at The Geysers include UNOCAL, the Northern California Power Agency, Pacific Gas and Electric, Calpine Corporation, and a consortium consisting of the Sacramento Municipal Utility District, the Modesto Irrigation District, and the city of Santa Clara.

Mountain in northern California. Three or four of the major sites, including Glass Mountain, have not yet been developed because of market or environmental factors. Most of the undeveloped fields are smaller, more moderate-temperature sites.

Figure 2.2: Known Fields for Geothermal Resources



Note: Hydrothermal reservoirs in the United States that offer potential for power generation with current or future technologies are located in the far western states. According to the U.S. Geological Survey, all of these western states, as well as others, have low-temperature reservoirs that are not suitable for power generation but could have the potential for direct-heat applications.

Source: U.S. Geological Survey.

The extent of undiscovered sites is highly uncertain. Bureau of Land Management officials responsible for managing geothermal leases on federal lands believe that most if not all of the major high-temperature hydrothermal sites have now been discovered. However, DOE officials believe there may be 20 to 30 undiscovered sites, each of which could produce between 100 and 200 megawatts of geothermal power. But since these sites lack surface manifestations, discovery will require sophisticated geophysical techniques. DOE officials told us that geothermal developers were attracted to the known sites first; therefore, the hidden sites have received little attention.

Hot Dry Rock Technology Is Not Economically Viable in the Near Term

Natural hydrothermal systems that are both hot enough and large enough to supply significant amounts of power are limited. They occur in relatively few locations and represent only a small fraction of the heat energy within the earth's crust. To obtain energy from accessible regions of the earth's crust that lack hydrothermal systems, the federal government has put considerable effort into developing hot dry rock technology. This technology extracts energy by drilling into the earth's hot layers, pumping water through these layers to create steam or hot water, and extracting the heat to generate electricity.

Since 1973, DOE has invested about $175 million in its hot dry rock program. This program, directed by the Los Alamos National Laboratory, has shown the technology to be technically feasible but has not demonstrated that it can be commercially viable.

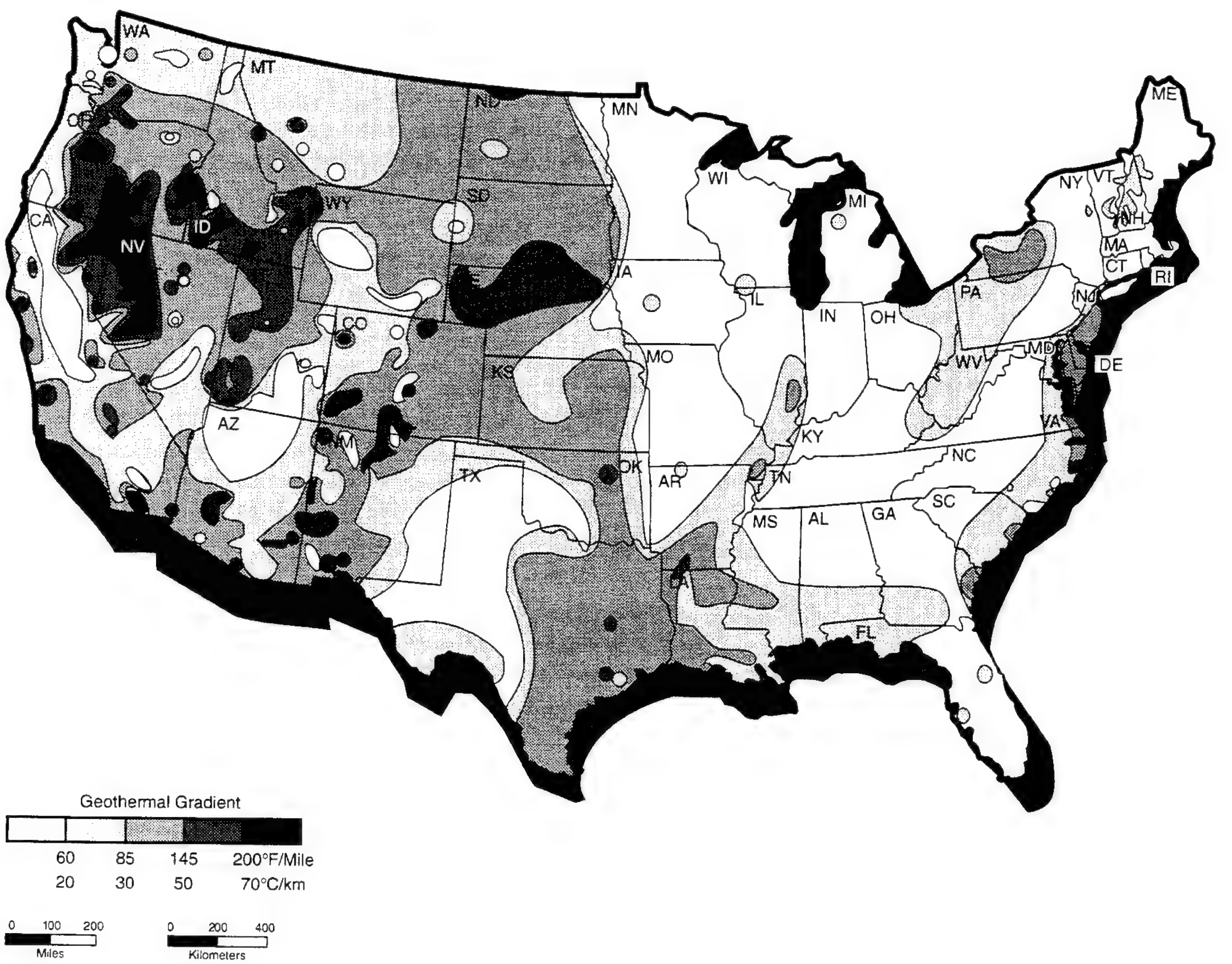
Most of DOE's efforts have gone into developing a hot dry rock test facility at Fenton Hill, New Mexico. At this site, researchers drilled an 11,500-foot well into rock with a temperature of about 430 degrees Fahrenheit. They then fractured the rock at that depth by pumping water at very high pressure to create a reservoir with a volume of 16 million to 20 million cubic meters. Once the reservoir had been created, the researchers drilled a second well and succeeded in pumping water at high pressure (nearly 4,000 pounds per square inch) down one well and retrieved steaming hot water from the other. The temperature of the injected water was about 80 degrees Fahrenheit, and the temperature of the retrieved water was about 360 degrees Fahrenheit—sufficiently hot to generate electricity.

Although the Fenton Hill test facility demonstrated the technical feasibility of using hot dry rock technology for extracting heat to generate electricity, questions remain about the technology's commercial viability. According

to geothermal companies, hot dry rock technology is not economically feasible in the near term. It is more expensive than hydrothermal production because it requires drilling deeper, finding an outside water source, creating a reservoir, and injecting the water at high pressure. Consequently, most current geothermal operators are not interested in becoming involved in its development at this time, since less costly hydrothermal operations are having a difficult time competing with relatively inexpensive natural gas as a power source.

In addition, hot dry rock energy extraction faces questions about its sustainability, much as do hydrothermal resources. Since the conductivity of heat in the rock is much slower than the convection of heat in the water, a U.S. Geological Survey official predicted that the rock surrounding the reservoir may begin to cool within 5 to 10 years. Water loss is also a concern. Water loss varies from site to site, depending on the pattern of fractures in the rock. While the Fenton Hill project showed a water loss of only 10 percent, the loss might be greater or lesser at another site. According to the head of the U.S. Geological Survey's Geothermal Studies Project, one fracture in the rock could result in large water losses that would significantly compromise the viability of the project. Another obstacle to hot dry rock energy extraction is that most areas with potential are located in the arid western regions of the United States where water for injection is scarce and expensive. Figure 2.3 shows the areas that the U.S. Geological Survey has identified as having the most potential for producing energy from hot dry rock.

Figure 2.3: Areas With the Highest Potential for Hot Dry Rock Energy Production



Source: DOE.

Now that DOE has proven the technical feasibility of hot dry rock technology, it has suspended further testing at the Fenton Hill test facility. Rather than become the primary investor in further demonstration

projects, it has chosen to help fund projects that industry supports. DOE has put out a notice of interest to cofund a semicommercial hot dry rock demonstration project.

Market Barriers Limit Growth

Several market factors limit the growth potential of geothermal power. First, many utilities located in areas with geothermal resources have little demand for additional power capacity. Second, the current low price of natural gas makes geothermal power economically undesirable. Finally, the decline of assured markets and the corresponding increase in competitive bidding have compromised the development of new geothermal fields.

Utilities in Geothermal Resource Areas Lack Demand for Additional Power

Before geothermal developers can expand production or develop new fields, they must find utilities that will purchase the power they generate. However, many of the utilities located in areas with geothermal resources need little additional power because their capacity for generating electricity was extensively expanded during the 1980s and demand-side management programs were implemented.[4]

For example, officials from California's two largest utilities, Pacific Gas and Electric and Southern California Edison, told us that they are well positioned to meet most demand growth in the 1990s through vigorous demand-side management programs and some repowering of old plants. Furthermore, interest in geothermal power in Utah and New Mexico is dampened because major utility companies there report excess capacity and have no plans for expanding their power-generating capability.

Geothermal Power Has Difficulty Competing With Power From Lower-Cost Sources

In the 1990s, the high price of geothermally produced electricity has reduced its competitiveness with electricity generated from lower-priced fossil energy sources, such as natural gas. In 1993, electricity generated from natural gas cost the utility about 4 cents per kilowatt hour to generate, while electricity generated at geothermal sites cost the producer between 5 and 7 cents per kilowatt hour. The higher cost of generating electricity at a geothermal plant is attributable to the higher up-front capital costs for drilling and plant development.

[4]Demand-side management programs reduce the need for electricity. Such programs include those that encourage the use of more efficient appliances or machines and those that shift the demand for electricity to off-peak times.

In Nevada, the availability of fossil fuels will make it difficult for geothermal power plants to compete for two reasons. First, Sierra Pacific Power, the utility company that serves most of northern Nevada, is proposing to build a new natural gas pipeline that would bring low-cost natural gas to the area for generating electricity. Second, DOE is planning to subsidize the cost of using coal to produce electricity by spending $135 million under the Clean Coal Technology Program to cover half the cost of building a 100-megawatt coal plant and of operating it for the first 4 years.

New Development Is Compromised Without Assured Markets

Geothermal investors are reluctant to take the risk of funding the costly exploration and development of new resources without assured markets. Assured markets would guarantee that the electricity generated from geothermal sources would be purchased for a set period of time. Assured markets were provided in California through the state's Standard Offer 4 contracts.

According to officials in California's Public Utilities Commission and Energy Commission, most geothermal development occurred in the 1980s under California's Standard Offer 4 contracts, which required utilities to offer power contracts to qualified geothermal producers. These officials also said that this program assured producers that they could market their power should they successfully discover and develop a new field. Furthermore, they said, Standard Offer 4 contracts ensured a relatively high price per kilowatt hour that could be used to help offset the higher up-front capital costs of geothermal development. For example, a Standard Offer 4 contract beginning in 1988 would give the operator an average price of about 9.75 cents per kilowatt hour over the 10-year period of the contract. However, these contracts are no longer available, and utilities in California and other states are increasingly using competitive bidding to award new contracts. Consequently, rather than having an assured market, geothermal developers must now compete with producers that use other, lower-cost energy sources, such as gas and coal, to produce electricity.

The Federal Government Is Seeking to Enhance Markets and Develop New Fields

Several federal efforts are under way to encourage the development of new geothermal sites. First, DOE is undertaking numerous research and development efforts to make geothermal technology more competitive. Also, the Bonneville Power Administration has a pilot program to support geothermal development in the Northwest. In addition, DOE is planning an industry-coupled drilling program to encourage exploration for new geothermal fields, and the Department of Defense is using proceeds from the Coso geothermal site to fund exploration at other military facilities. Finally, the Energy Policy Act of 1992 established permanent investment tax credits for geothermal development.

DOE Sponsors Research and Development

One of the goals of DOE's geothermal program is to assist industry in bringing down the cost of geothermal production through research and development aimed at advances in such areas as drilling and energy conversion technology. Many industry officials stated that these efforts could help reduce the cost of production, thereby enabling developers to win more power contracts. Prior geothermal program research and development efforts, such as the development of the more durable polycrystalline diamond compact drill bit, have reduced costs and benefited oil and gas as well as geothermal drillers.

Drilling costs, which account for 30 to 50 percent of the cost of developing a geothermal power plant, continue to be targeted by industry for reduction. At the Sandia National Laboratory, DOE is funding an effort to determine whether a technology called "slim-hole" drilling could be used to bring down development costs. Currently, developers typically spend over $1 million to drill a full-sized geothermal well (about 8 to 12 inches in diameter) to test a site's potential for producing geothermal power. Many of these wells are not productive. If slim-hole drilling, which produces a hole 3 to 4 inches in diameter, could be used instead to test a site's potential, the costs of exploratory drilling might be cut by more than half.

The National Academy of Sciences, under a DOE contract, is studying the feasibility of significantly reducing the cost of drilling through advanced drilling techniques, such as high pressure water jets or lasers. This study is expected to be released in February 1994.

DOE is also supporting efforts to improve the efficiency of geothermal power plants. For example, DOE is cofunding a demonstration project to validate the "Kalina Cycle," a technology that may increase the efficiency of closed-loop geothermal plants by 40 percent. The Kalina Cycle uses a

working fluid that is a mixture of two components with widely different boiling points, ammonia and water. By varying the ratio of these components at various points in the steam cycle, DOE can achieve greater generating efficiencies. To aid in developing this technology, the DOE Geothermal Division has contracted with the National Institute of Standards and Technology to develop standard ammonia and water data tables.[5] If the Kalina Cycle application for geothermal plants is successfully developed, a DOE-sponsored study projects that it would not only increase generating efficiency at moderate-temperature sites but also make development at lower-temperature geothermal sites more viable.

Finally, DOE has funded other research and development projects that are aimed at reducing the costs of developing and operating geothermal facilities. These include improving geophysical methods for identifying potential geothermal sites, developing materials used in drilling and extraction that better withstand high-temperature corrosive geothermal brine fluids, and developing an economically and environmentally acceptable method for disposing of geothermal wastes and converting by-products to useful forms.

The Bonneville Power Administration Is Conducting a Pilot Project

The Bonneville Power Administration is encouraging the development of two new geothermal sites in Oregon by offering power contracts in advance of field development. By offering an assured market, Bonneville has enabled two geothermal companies, one large and one small, to start developing new fields. The companies assume the financial risk involved in exploration and development, since, if the projects are not successful, the companies will have nothing to sell Bonneville.

Bonneville has agreed to pay a high price (about 10 cents per kilowatt hour) on a portion of the production from these sites for the first 10 years to allow the geothermal developers to recoup their initial capital investment. In return, Bonneville will pay a low price (about 3 cents per kilowatt hour) during the remaining 35 to 40 years of the contracts. According to a Bonneville official, the average cost per kilowatt hour over the lifetime of the contracts should make geothermal power competitive with other sources of power. Bonneville and participating utility company officials maintain that this strategy is an excellent way to encourage geothermal development in new areas.

[5]Data tables provide properties of ammonia and water mixtures at various concentrations, pressures, and temperatures.

Other Federal and Industry Efforts Support Geothermal Development

DOE plans to cofund an industry-directed exploratory drilling program to find new geothermal resource areas. Initially, DOE plans to allocate $2 million to support two such projects in 1995, and it may expand the program in future years. While markets for the power from such sites may not now exist, DOE officials believe that in 5 to 10 years demand will grow and markets will open.

Standard Offer 4 contracts with Southern California Edison provided a market for power from the Department of Defense's Coso site at China Lake in eastern California. The program director told us that the Department plans to use the proceeds from these contracts to investigate and possibly develop geothermal sites at other military facilities.

To encourage a market for geothermal power, the Energy Policy Act of 1992 made permanent the federal investment tax credit for geothermal development initiatives. Credits allowed under the act could help offset the high drilling costs, thus making electricity produced from geothermal sources somewhat more competitive.

Environmental Concerns Have Affected Some Geothermal Developments

The environmental problems associated with geothermal power production are fewer and less serious than those associated with fossil fuels. Nevertheless, some geothermal power producers have had to address environmental challenges, such as abating emissions of dissolved gases and disposing of waste sludge. Others have faced opposition from interest groups opposed to industrial development in scenic areas.

Emission Abatement Is Successful but Adds to Cost

Since geothermal power generation entails no combustion, its emissions are limited to dissolved gases, brine, and sludge released during depressurization in open-cycle systems. Newer closed-cycle plants have essentially no emissions, since what comes out of the ground is circulated back into it.

Geothermal operators of open systems have taken appropriate, and in some cases quite extensive, pollution control measures. According to local and state officials, these actions are allowing geothermal operations to comply with state and local emission standards. However, the cost of compliance adds to the operating cost. For example, at The Geysers, significant amounts of hydrogen sulfide as well as smaller amounts of arsenic and other minerals come up with the steam. One operator at The

Geysers estimated that 60 percent of their operating cost is attributable to, and 70 to 80 percent of their time is spent on, abatement systems.

At the Salton Sea reservoir in California, the hydrothermal fluid has a high concentration of salts and minerals, and the operator must dispose of a significant amount of sludge. The sludge contains barium sulphate and radium (a naturally occurring radioactive substance that eventually breaks down into radon gas). To dispose of the sludge, the operator spent over $2 million to build a disposal facility with a capacity of 300,000 cubic yards. The operator also planned to build a second such facility. In March 1994, DOE informed us that the operator had recently developed a method for keeping the "sludge" in solution; now it is injected into the ground along with the spent geothermal fluid.

Opposition to Development in Scenic Areas Slows Growth

Many hydrothermal resources are located in scenic areas. Those in national parks, such as Yellowstone and Lassen National Parks, are blocked from development. At other locations, such as the Oregon Cascades and the Hawaii rain forest, geothermal resources lie in areas where there are significant land-use concerns involving nature preservation and recreational access. In some cases, environmental reviews and the permitting process have blocked or significantly delayed the development of production fields.

Conclusions

The outlook for significantly expanding electricity production from geothermal energy is not promising because of resource limitations and market barriers. Most of the known large fields have already been developed, and operators are extracting energy from them faster than nature can replace it. Hence, these fields will not be sustainable for the long term. Market barriers, such as the availability of lower-priced fossil fuel alternatives and California's elimination of assured markets, further limit the potential of geothermal energy production. To reduce barriers, the federal government has supported efforts such as DOE's research and development programs and the Bonneville Power Administration's assured market program; however, these efforts are not likely to significantly increase the generation of electricity from geothermal energy.

Agency Comments and Our Evaluation

DOE considered our report unduly pessimistic in its discussion of the outlook for generating electricity from geothermal resources and suggested that evidence had been selected to bolster a particular

conclusion. We disagree. We believe that the report presents a balanced view of the prospects for generating electricity from geothermal energy and that it draws logical conclusions from the available geological and marketing evidence, including data from DOE. For example, at a hearing on March 10, 1994, before the Subcommittee on Energy and Water, House Committee on Appropriations, the Assistant Secretary, Energy Efficiency and Renewable Energy, presented projections in support of DOE's fiscal year 1995 budget request, showing 4,000 megawatts of geothermal capacity by 2000, a 23-percent reduction from a 1993 DOE projection. At 4,000 megawatts, geothermal's capacity would still represent less than 1 percent of the nation's total generating capability at that time. Other factors that we discuss in the report also limit the outlook for geothermal capacity, including (1) the absence of major new geothermal fields, (2) the decline of production from existing fields, and (3) market factors, such as the current low price of fossil fuels, which makes them more economically attractive than other energy sources.

DOE commented that the report is excessively pessimistic about the longevity and productivity of geothermal reservoirs. According to DOE, recent lessens learned at The Geysers and the cumulative results of nearly 2 decades of research and development are yielding impressive results. We believe that our report accurately captures the longevity and productivity problems at geothermal reservoirs. As we explain in this chapter, operators at The Geysers told us that the resource's capacity is expected to decline by about 50 percent over the next 20 years, from 1,220 megawatts in 1993 to about 600 megawatts. In addition, we discuss some of the research and development projects that geothermal companies say may help reduce the cost of producing geothermal electricity and make it more competitive with other power sources.

Appendix IV contains our detailed evaluation of DOE's comments.

Potential for Growth of Geothermal Direct Use Is Limited

Low- to moderate-temperature geothermal resources suitable for direct-heat applications are widely distributed throughout the western and midwestern United States and offer a sustainable, environmentally benign resource alternative. The federal government and a few western states, primarily California, have fostered growth and development through cofunded demonstration projects and financial and technical assistance. While these activities helped foster growth in direct-use applications in the 1980s, prospects for growth are not promising because of the continued low price of energy from fossil fuels, the relatively high up-front capital costs and drilling risk associated with locating and developing productive geothermal wells, and the lack of site-specific resource information and data needed to assess drilling risks and resource potential.

Growth of Direct Use Is Affected by Location of Resource and Price of Fossil Fuels

In the 1980s, growth in direct-heat geothermal use accelerated as more industrial and agricultural uses became operational. Direct-use applications include space heating of individual structures, district heating of multiple buildings using geothermal heat distributed from a central location, agricultural and industrial heat-processing applications (growing mushrooms, drying fruits and vegetables, desalinizing water, and leaching precious metals), and aquaculture (raising freshwater fish and marine organisms). Geothermal heat is also used directly to heat spas and swimming pools.

Before 1977, the primary applications of geothermal direct-use energy resources were resorts and health spas and a small number of space- and district-heating systems that were located near geothermal resources. The oil shocks of the 1970s and subsequent government initiatives to spur the development of alternative energy sources allowed larger-scale geothermal operations to develop and were responsible for much of the growth in direct-use applications and capacity in the 1980s. However, while geothermal resources are abundant in the western United States, the distance separating this resource from major population centers and the relatively low cost of fossil fuel will limit growth prospects.

In 1993, the Oregon Institute of Technology's Geo-Heat Center compiled a list of 308 direct-heat projects operating throughout the United States that had a total capacity of about 450 thermal megawatts (see table 3.1).[1] In 1980, the total direct-use capacity in the United States was estimated at 111 thermal megawatts.

[1]The Geo-Heat Center serves as a clearinghouse for accumulating and disseminating technical information and data on direct use as well as for providing technical and engineering assistance to individuals and individual projects.

Table 3.1: U.S. Geothermal Direct-Heat Projects

Application	Number of sites	Capacity in thermal megawatts
Space heating	102	74
District heating	17	96
Greenhouses	38	81
Aquaculture	24	102
Resorts and pools	115	69
Industrial processes	12	29
Total[a]	**308**	**451**

[a]Enhanced oil recovery is not included. Although oil companies use water from geothermal sites, they do not use heat.

Resources Are Abundant in the Western United States but Not Easily Accessible

Studies conducted in 1978 and 1982 by the U.S. Geological Survey indicate that the resource base for low- to moderate-temperature geothermal energy is very large and widely distributed throughout the western and midwestern United States as well as in a few isolated regions in the east. The 1982 study pointed out that although high-temperature resources (above 300 degrees Fahrenheit) are relatively rare, low- to moderate-temperature resources (between 90 and 300 degrees Fahrenheit) are more widespread, especially at the lower end of this temperature range.

Geothermal direct use, however, is constrained because the resource cannot be economically stored and transported. Hence, applications must be located near the geothermal resource. Despite the abundance of geothermal energy throughout the western states, only a portion is accessible to population centers where the direct-heat resources can be converted effectively and efficiently to useful applications.

Growth Prospects Depend on Fossil Fuel Prices

According to Geo-Heat Center and University of Utah Research Institute officials, one of the difficulties in estimating the ultimate potential contribution of geothermal energy is that future energy costs are uncertain. If fossil fuel costs were to increase, many lower-grade geothermal resources would be economical to develop.

A DOE contractor projected annual growth to the year 2010 under two different scenarios. For the high-case scenario, the contractor assumed that the government would continue to provide financial assistance and

incentives[2] and that the price of fossil fuel would continue to rise. For the base-case scenario, the contractor used historical data and assumed a "business as usual" environment (see table 3.2).

Annual growth rates projected by the DOE contractor range between 10 to 12 percent for the high-case scenario (except for resorts and pools). For the base-case scenario, annual growth rates range between 0 and 8 percent.

Table 3.2: Annual Growth Projections to 2010 for Base-Case and High-Case Scenarios

Projections in percent

Applications	High-case scenario	Base-case scenario
Space and district heating	12	2
Greenhouses	10	1
Aquaculture	11	8
Industrial processes	11	5
Resorts and pools	0	0

Government Assistance Fostered Industry's Growth

Following the oil crisis of the 1970s, which spurred interest in alternative energy sources, DOE initiated many programs to encourage private and municipal development of low- to moderate-temperature geothermal resources. The programs provided technical and engineering assistance, cofunded demonstration projects, and funded loan guarantees, resource assessments, and other activities. Among the western states, California established its own geothermal grant and loan program in 1980 to encourage direct use of the state's vast geothermal resources.

Federal Government Assistance Accelerated Past Growth

Historically, the main applications for direct uses of geothermal energy were small resorts and a limited number of space- and district-heating systems. Beginning in 1977, DOE issued two Program Opportunity Notices (PON), inviting private and municipal developers to share the cost of various direct-use demonstration projects. These notices resulted in 23 direct-use projects involving district heating of multiple buildings in townships (8); institutional heating of schools (3), hospitals (3), community centers (2), and a prison (1); industrial processing for food (1) and sugar beets (1); and agribusiness applications for greenhouses (2), a fish farm (1), and a ranch (1). The federal government contributed

[2]Federal incentives could include resource assessment and evaluation, cost-shared demonstration projects, and low-cost loans or loan guarantees and tax credits.

$25.1 million (76 percent) of the $33.2 million in total geothermal heating system costs for the 23 projects. The 23 PON projects are listed in appendix II.

More recently, direct government funding and assistance were also provided to other direct-use projects through cooperative agreements and the solicitation of new technologies that use low-temperature resources. For example, DOE is currently funding two projects through its Idaho field office—$890,000 for expanding the city of Boise's district-heating system and $206,000 for using cascaded fluids from an existing geothermally heated greenhouse to heat an aquaculture facility at the Southwest Technology Development Institute at New Mexico State University.

In addition, since 1977, DOE has funded the Geo-Heat Center. Over the past several years, DOE has provided $300,000 a year for the Geo-Heat Center's direct-heat utilization assistance program and additional funding for the center's research and development activities that support various system applications and designs. From 1988 to 1990, the Geo-Heat Center provided technical assistance to 81 projects, supplying resource information, reviewing and assisting with system designs, and troubleshooting problems on completed projects. It also analyzed and reported on problems in operating the equipment and materials used in 13 major district-heating systems, published topical papers and a quarterly bulletin, and participated in 39 technical and nontechnical presentations.

Finally, in 1991 the Congress appropriated $1.5 million for DOE to contract with academic and state institutions to work with potential direct-heat developers. Three institutions—the Geo-Heat Center, the Earth Science Laboratory at the University of Utah Research Institute, and the Idaho Water Resources Research Institute at the University of Idaho—received DOE contracts to collaborate on the program.

Through this program, DOE will compile geothermal resource and demographic data on the most promising geothermal locations in the western United States, and it will undertake research and development on better methods for locating geothermal resources, testing wells, and modeling hydrology. Other components of the program involve geothermal heat pumps (see ch. 4) and a public education outreach effort. Expected to last 5 years, this program has already received funding for the first 2 years.

California Is Assisting Geothermal Developers

Since 1981, the California Energy Commission (CEC) has promoted the development of geothermal direct uses by extending financial and

technical assistance to public entities. Since 1990, it has similarly assisted private entities. Over the past 12 years, California has provided $26.2 million in grants and loans for 84 commercialization and development projects.

California Assembly Bill 1905 (enacted in 1980) established a long-term source of funds for direct-use geothermal development. The bill provided for California's share of federal geothermal lease revenue to be distributed among three entities—40 percent to the counties where the geothermal leases are located, 30 percent to CEC for its geothermal grant and loan program, and 30 percent to the state for environmental and conservation programs.

In total, CEC has financed the drilling of more than 50 exploration, production, and injection wells in an effort to develop the state's lower-temperature resources. Additionally, CEC provided funding for many other direct-use applications for space and water heating of schools, hospitals, and other public and privately owned buildings. Most of these funds will be repaid, enabling CEC to fund new geothermal projects.

In the early 1980s, CEC placed more emphasis on generating electricity from geothermal energy, but more than 90 percent of the funds currently available through CEC are being used to develop low- to moderate-temperature resources. The following three CEC projects demonstrate the extent of the state's efforts and support for developing geothermal resources. CEC provided

- $3.6 million of the $5.6 million in development and construction costs for a city of San Bernardino district-heating system that serves 34 buildings;
- $492,000 of the $697,000 in total costs for a Lake County agricultural greenhouse and agriculture park for vocational training and research by faculty and students of a nearby community college; and
- $765,000 of the $861,000 in total costs for a resource assessment program and for exploratory drilling programs to explore the feasibility of developing district-heating systems for the cities of Loma Linda and Colton.

Several Barriers Inhibit Growth

Among the principal barriers to developing geothermal direct-use applications are the relatively high up-front capital costs and the drilling risks associated with locating and developing geothermal resources. Furthermore, low fossil fuel prices discourage any change in current

sources of energy. Finally, the lack of site-specific resource information, including the geological and geophysical data needed to assess drilling risks and resource potential, can further deter potential users from considering geothermal heat.

Capital Costs and Drilling Risks Are High

Energy companies have shown little interest in exploring for or developing low- to moderate-temperature geothermal resources because of the relatively low rate of return on their investment compared with the high cost and the high risk associated with exploration and drilling. These high costs and risks have kept many local governments, private investors, and industrial and commercial users out of the direct-use market as well.

Exploratory drilling is risky because of the chance of hitting a "dry hole" or finding geothermal fluids that do not meet temperature or heat flow requirements. Neither DOE nor its laboratories have accumulated actual data on the success rate for drilling wells; however, 6 of 23 projects sponsored under DOE's PON program were abandoned because of inadequate geothermal resources, and a seventh project was abandoned because of drilling problems. The government spent $9.3 million on these projects before abandoning them (see app. III).

Low- to moderate-temperature geothermal reservoirs are generally found at depths of 500 feet (on average) to 3,500 feet. Drilling to these depths can be expensive, costing from a few thousand dollars to hundreds of thousands of dollars, depending upon factors such as the type of geothermal well (production or injection), the diameter of the bore, the type of terrain or geophysical location, the materials and equipment used, and the existence of drilling difficulties.

Table 3.3 shows that drilling represented 60 percent of the costs of constructing a commercial geothermally heated greenhouse project located near Salt Lake City, Utah. DOE funded 66 percent of the costs, including all of the drilling costs, and therefore assumed all of the drilling risk. The well had a target depth of 3,000 feet, but insufficient temperature and fluid flow required drilling the well to a depth of 4,994 feet. The geothermal heat replaced one-third of the previous energy from oil and natural gas and supplied about 44 percent of the total net heating needs for the 7-acre greenhouse facility. A DOE consultant calculated the payback period for the geothermal heating system's cost at 8 years. The contractor reported that the greenhouse owner considered the project only marginally successful, however, because the geothermal system was

unable to replace all of the fossil fuel needed for heat. The greenhouse owner told us that if the government had not funded the drilling cost ($416,000) and assumed the drilling risk, he probably would not have pursued the project.

Table 3.3: Cost of Drilling for a Salt Lake City, Utah, Greenhouse Heating System

Activity	Capital costs	Percent of costs
Resource confirmation		
Drilling and testing	$416,000	60
Environmental and geological	20,000	3
Geothermal supply system	205,000	30
Reports, technical papers	21,300	3
Project management, permits	24,700	4
Total	**$687,000**	**100**

The high capital cost that many in the industry have identified as a major barrier to the greater direct use of geothermal resources is further illustrated in a 1983 DOE-funded economic analysis of nine demonstration projects cofunded by the government under DOE's PON program.[3] This program enabled prospective users of geothermal resources to obtain government cost-sharing for the high front-end cost, thereby reducing the users' financial risk. The capital cost for five district-heating projects ranged from $1 million to nearly $4 million, while capital costs for four space-heating systems ranged from $270,000 to over $1 million. The capital cost excluded the cost of converting tenant buildings on the district-heating network to geothermal capability. Drilling and construction costs for putting the system together (installing piping, heat exchange equipment, pumps, and plumbing) were the largest cost components in the geothermal systems.

Furthermore, bringing a geothermal project into operation does not ensure its continued functioning. Of the 16 projects that became operational, 5 were eventually shut down for various reasons, including high operating costs, equipment failure, personnel support problems, and a facility's closure. The government spent $3.5 million on these terminated projects (see app. III).

[3]An Economic Assessment of Nine Geothermal Direct Use Applications, ICF, Inc. (Washington, D.C.: Dec. 1983).

Low Fossil Fuel Prices Affect Cost-Effectiveness of Geothermal Uses

To be economically viable, a geothermal system must supply heat at a price that is competitive with the price of the cheapest available alternative heating method. Currently, the low prices of competing fossil fuels, such as natural gas, discourage any change in the use of fossil fuel energy and put geothermally produced energy at a competitive disadvantage. Natural gas, the dominant heating fuel, has captured 52 percent of the market share nationally. The market share for natural gas is higher in some western states: In California, for example it is above 70 percent.

Once a geothermal system has been installed, its lower operating and maintenance costs can save customers up to 50 percent on their heating bills. However, the opportunity for a geothermal system to recover its capital cost and return a profit to its investors depends upon many factors, including the price that can be charged the end-users, the price of current energy alternatives, and the amount of government financial and technical assistance received.

To determine the economic potential of direct-use geothermal energy, DOE sponsored a study in 1983 on nine PON projects (six district-heating and three space-heating) that compared the costs and performance of each project with projections of the costs and performance of similar projects heated with natural gas and fuel oil (assuming a 15-year life for all of the projects). The results indicated that, from an operation and maintenance perspective, five PON projects were economical and four were uneconomical.

However, the study did not include federal contributions for resource exploration and technical assistance. Including these costs would have significantly increased the cost of geothermal energy. A more recent analysis, performed in 1990 by university researchers,[4] concluded that for some PON projects to be economically viable, higher-than-average natural gas prices would be required.

Data Limitations Restrict Development

According to Geo-Heat Center officials, the lack of a data base containing information on the locations of low-temperature resources is a further barrier to wider use of direct-use geothermal resources. In July 1992, at a congressional hearing on the direct use of geothermal resources before the Subcommittee on Environment, House Committee on Science, Space, and Technology, speakers from DOE, the U.S. Geological Survey, the

[4]R. Harrison, et al., Geothermal Heating: A Handbook of Engineering Economics (1990).

Geo-Heat Center, and the Natural Resources Defense Council contrasted the large potential of the U.S. resource with the small portion used. Yet, according to the Geo-Heat Center, much of this resource has not been assessed or defined for direct use; hence, further data-gathering, exploratory testing and confirmation are needed. A more complete resource data base would lower the risk for developers and users in finding and developing geothermal resources.

In fiscal year 1991, the Congress appropriated $1.5 million for DOE to begin funding a low-temperature reservoir assessment program that would promote the growth of geothermal direct use. One of the program's main objectives is to identify and prioritize those resources having the highest potential for economic development with significant benefits. To accomplish this, DOE is compiling available information from 10 western states on the characteristics of low- to moderate-temperature resources located within 5 miles of population centers. DOE expects to complete this compilation in the first half of fiscal year 1994.

In an earlier inventory conducted in 1980 for DOE, 1,277 hydrothermal sites were identified near 373 western cities. The 1980 inventory, however, was limited to eight states and did not include low-temperature uses for agriculture, greenhouses, or aquaculture. The new study will cover 10 states and include resources for industrial and agricultural processes. Officials at the Geo-Heat Center believe the new inventory of collocated resources and population centers will indicate a resource potential more than 10 times greater than estimated in 1980.

Direct-Use Geothermal Systems Create Minimal Environmental Impacts

The impact of geothermal direct-use projects on the environment is often minimal compared with that of large-scale electrical generation projects. Direct-use projects are often designed as closed circulation systems in which the spent geothermal fluids are reinjected into the water reservoir. From such direct-use projects, emissions of air, water, or solid waste are typically very limited.

According to DOE national laboratory officials, direct-use projects designed as open circulation systems that release geothermal fluids onto the earth's surface may pose environmental concerns because the fluids generally contain higher levels of chemicals than surface water. These chemicals can include hydrogen sulphide, boron, fluoride, and in some cases radioactive species. However, the rate at which fluids containing such chemicals can be discharged into surface water is limited by EPA and by

state environmental regulatory agencies. For direct-use facilities, as for geothermal generating facilities (discussed in ch. 2), the cost of complying with these standards adds to the operating costs.

Conclusions

Geothermal resources, while abundant in the western United States, are not easily tapped without major funding. The up-front capital costs and drilling risks for locating and developing productive geothermal wells remain major obstacles for developers and operators of direct-use facilities. Growth in larger-scale applications, such as district- and space-heating systems for buildings occurred as a direct result of both federal and state assistance. The federal government and California have geothermal programs that support the industry's growth, but low fossil fuel prices discourage development. The government's funding of a data base of geothermal resources located near population centers should help local municipal governments and developers identify resources and potential direct uses. However, until the price of alternative fuels rises, any significant growth in the use of this geothermal resource will be limited.

Geothermal Heat Pumps Could Meet More of the Nation's Heating and Cooling Needs

Geothermal heat pumps (GHP) take advantage of the constant temperature of the subsurface earth to provide the most energy-efficient and environmentally safe means to heat and cool buildings. In most parts of the country, GHPs—or ground source heat pumps, as they are also called—offer homeowners and building owners the lowest life-cycle cost for heating and cooling. While this technology has existed for over 30 years and the number of installed units has grown in recent years, this number accounts for less than one half of 1 percent of the space-conditioning systems in use in the United States today. Key to greater acceptance of this technology is more knowledgeable and better-informed consumers, building developers, and utilities.

Resource Potential and Prospects Are Promising

The relatively constant ground temperature (about 40 to 70 degrees Fahrenheit) found 3 feet or more below the earth's surface is suitable for heating and cooling most homes and buildings using geothermal heat pump technology. GHPs tend to be more efficient and more cost-effective in regions where the temperature swings between winter and summer are greater, but they can be installed almost anywhere in the United States and offer an economic alternative to heating and cooling systems that rely on fossil fuels.

GHPs Could Benefit Consumers, Utilities, and the Environment

Heating and cooling use about 40 percent of the electricity in residential and commercial buildings in the United States. GHPs can benefit the consumer, the utilities, and the environment because their highly energy-efficient properties lower energy consumption and air pollution while reducing customers' gas and electric bills.

In a 1993 study analyzing the efficiency and cost-effectiveness of competing heating and cooling technologies,[1] the Environmental Protection Agency (EPA) concluded that GHPs are consistently the most energy-efficient and environmentally clean space-conditioning system throughout the country. For northern climates with cold winters and for southern climates that remain hot for extended periods, the energy savings can be significant. The high efficiency of GHPs can reduce energy consumption by 23 to 44 percent over air source heat pumps and by 63 to 72 percent over electric resistance heating and standard air-conditioning equipment, depending on the location and climate conditions. For example, according to the DOE official responsible for GHP activity, for a

[1]Space Conditioning: The Next Frontier - The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money, EPA (Apr. 1993).

typical home, consumers can save between $300 and $800 in annual energy bills, resulting in a 3- to 8-year payback of the additional installation costs. Since residential space-conditioning equipment accounts for about 9 percent of the total U.S. annual energy consumption, we estimate that installing GHPs nationwide could save billions of dollars in energy costs each year.

The high efficiency of GHPs benefits utilities by lowering customers' energy consumption, especially during periods of the day when the demand for electricity is the greatest.[2] By encouraging energy-efficient technologies (such as GHPs) and conservation, the utilities can better manage peak load requirements, enabling them to defer construction of costly new generating facilities, utilize existing facilities more effectively, and help forestall increases in utility rates.

From an environmental standpoint, GHPs are clean and safe. They usually employ a closed-loop system consisting of a pressurized, sealed loop, usually filled with a mixture of water and antifreeze. Because the system is closed, the circulated fluids are physically isolated from the soil and there are no emissions. Furthermore, because GHPs use less electricity than other systems, generating requirements from gas and coal power plants are lessened, thus lowering the emissions of carbon dioxide, sulfur dioxide, and nitrogen oxides.

EPA determined that estimates of the relative impact of various heating and cooling equipment on air quality are influenced not only by operating performance and regional climate but also by assumptions about the fuel used to generate electricity in the region. Under most electricity-generating scenarios, EPA found that because GHPs used relatively little electricity compared with traditional heating and cooling systems, they were responsible for the lowest carbon dioxide, sulfur dioxide and nitrogen oxide emissions of all technologies analyzed and had the lowest overall environmental impact.

Few GHPs Have Been Installed, but Large Market Could Be Tapped

Despite their advantages, GHPs comprise a very small share—less than one-half of 1 percent—of the current space-conditioning market. DOE estimated that about 150,000 units had been installed as of 1992, for a total thermal capacity equal to nearly 2,100 megawatts. DOE estimated that sales of GHPs had grown from about 19,700 in 1989 to 29,000 in 1992, yet sales

[2]To meet load requirements during peak demand periods, utilities will often bring auxiliary generators on line or purchase electricity at premium rates.

remain a niche market that does not enjoy the economies of scale or the level of competition in most parts of the country that would reduce installation costs for consumers. In comparison, over 800,000 air source heat pumps are installed annually in the new construction and replacement markets for single-family residences, apartments, and commercial buildings.

EPA estimates that an aggressive program to promote GHPs could increase annual sales to 300,000 by the year 2000—a 10-fold increase. While the greatest activity to date has been in the single-family residential market, industry officials contend that commercial buildings, apartment complexes, and schools represent an even bigger market because they require more energy for heating and cooling and therefore have a greater savings potential.

For example, in Louisville, Kentucky, a 1,700-ton system (large enough to supply the energy needs of 560 homes) was installed in a hotel and apartment complex, reducing peak power demand by 47 percent and overall electricity consumption by 44 percent. Furthermore, a project at New Jersey's Stockton State College is expected to save over 2 million kilowatt hours of electricity and over 171,000 therms[3] of natural gas annually. Overall, the college expects to save over $360,000 annually in energy costs, resulting in a payback period of 3-1/2 years.

Market Barriers Hold Down Use of GHPs

Three barriers are restraining GHPs from capturing a larger market share. First, GHP technology is not widely known to consumers and installers throughout the country. Second, the higher initial installation costs discourage consumers from buying GHPs. Third, many states and utilities have not implemented efficiency and conservation programs that promote greater use of energy-efficient technologies such as GHPs.

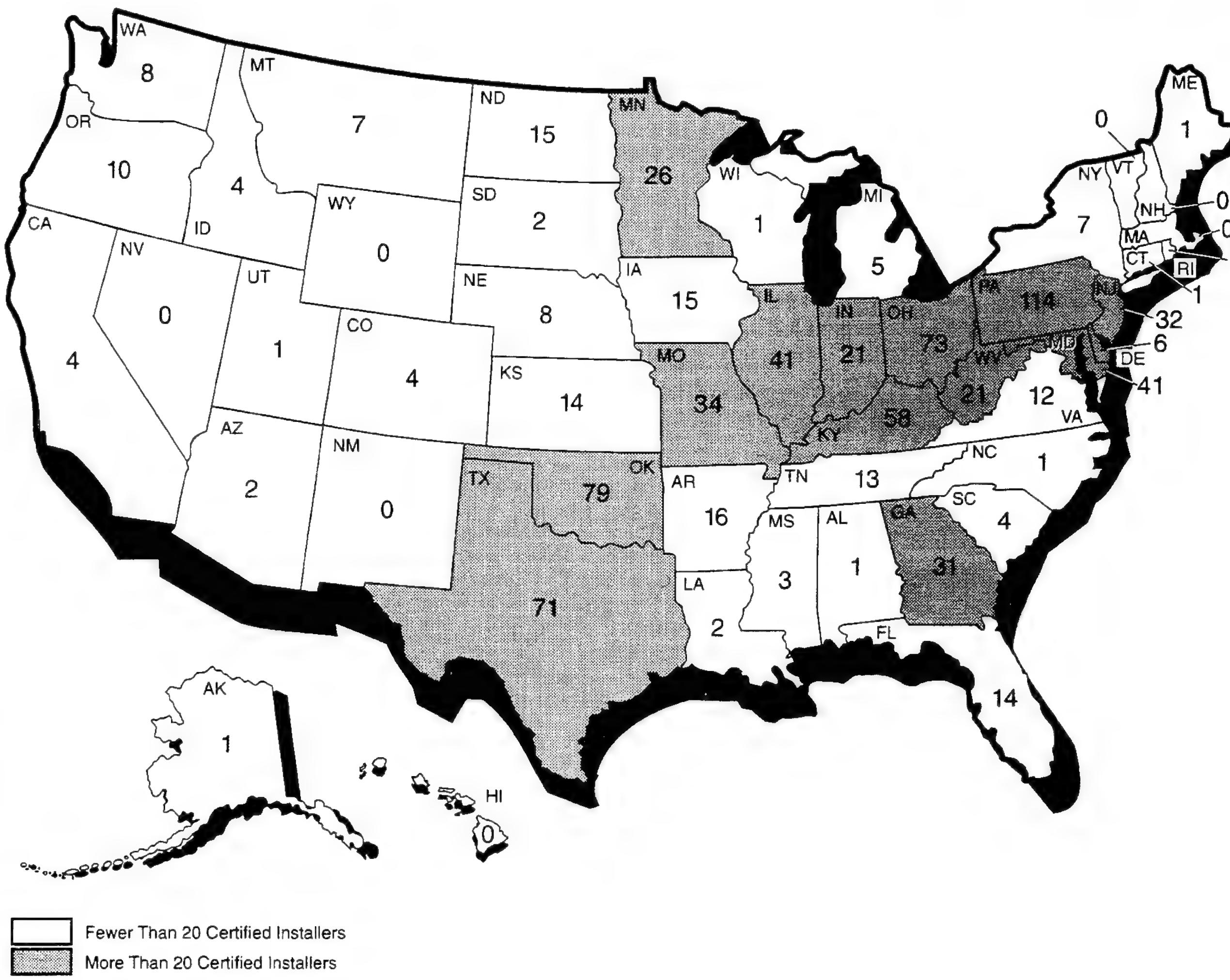
Consumers and Installers Are Unfamiliar With GHP Technology

Some industry and DOE officials contend that greater acceptance of GHP technology is constrained by the public's unfamiliarity with the technology. They believe that many consumers, builders, and utilities are not aware of the technology and its benefits. Furthermore, an insufficient number of trained system designers and installers has proven to be another constraint. The key component of GHP systems is the underground loop system. For this system to operate efficiently, its length and depth

[3]A therm is equivalent to 100,000 British thermal units (BTU). A BTU is a common unit of heat measurement for natural gas.

must match the soil's conductivity. Well-trained and experienced geothermal heat pump designers and installers are required to ensure that a reliable and efficient system is installed. However, in most parts of the country, such well-trained and experienced designers and installers are not available (see fig. 4.1).

Figure 4.1: Number of Certified GHP Installers in Each State, as of June 1993



Source: International Ground Source Heat Pump Association.

Consumers Balk at Higher GHP Installation Costs

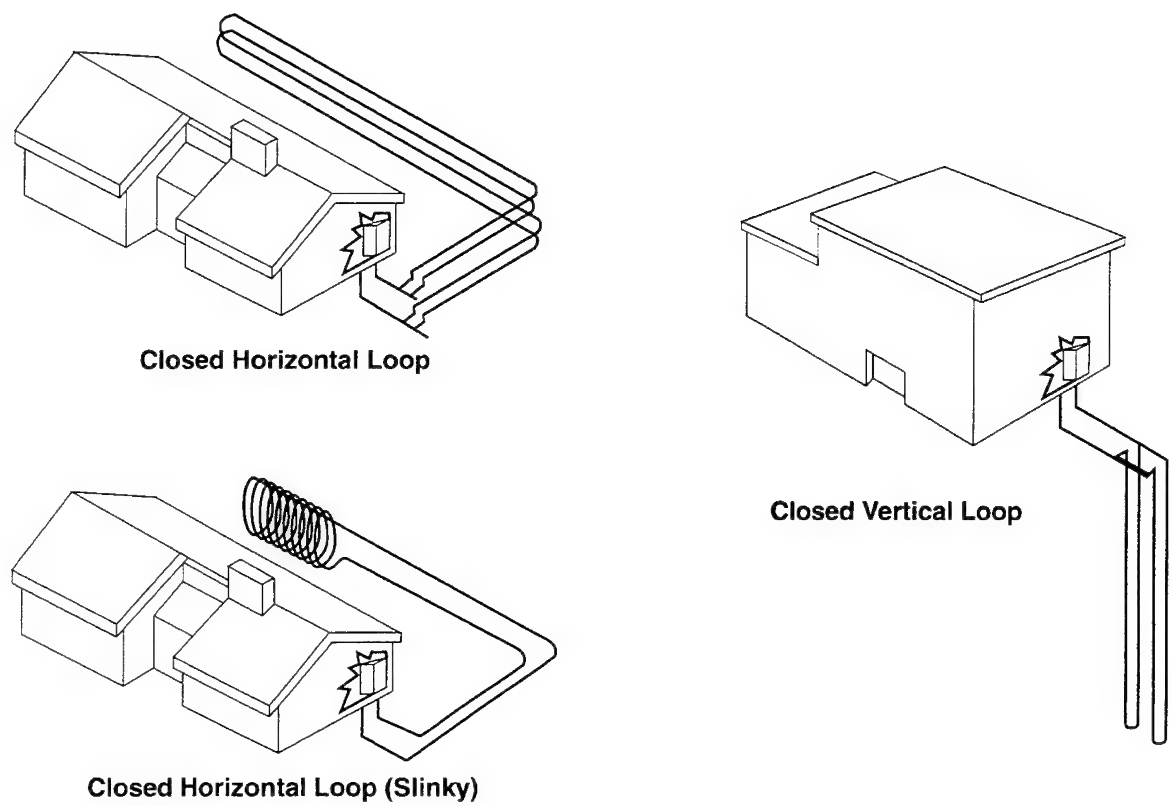
Even though GHPS can lower energy bills, consumers are reluctant to pay the high costs of installing them. The cost of the underground loop system makes the average residential GHP $1,050 to $3,000 more costly to install than other space-conditioning systems. While ongoing research and

development efforts could incrementally lower installation costs, many industry officials believe that market promotion and market penetration will significantly lower prices.

Industry, utility, and government officials agree that market promotion and market penetration are more likely than research to lower the cost of GHPs and should be given more emphasis. Yet DOE officials confirm that federal funding for promotion and outreach is more difficult to obtain than funding for basic research and development.

Industry and DOE are supporting research on new methods of installing the ground loop system, which are expected to lower costs. These efforts have produced the "slinky coil," whose ground pipes are manufactured into coils that are wound together rather than placed in a regular straight pipe pattern. This configuration reduces the area and size for the underground trenches (see fig. 4.2). Also being studied are drilling techniques that will allow multiple boreholes to be drilled from one location and improved grouting materials that can conduct heat well and be used to backfill trenches or boreholes.

Figure 4.2: Diagram of Alternative Underground Pipe Systems



Source: DOE.

In states where utilities and industry have actively supported the marketing and selling of GHPs, the installation costs have come down. Industry and utility officials attribute these reductions to economies of scale associated with a higher number of units installed and a more competitive marketplace. For instance, some home builders in Indiana have designed and installed an entire subdivision of new homes using GHPs. As a result, Public Service of Indiana studies indicate that the installation costs for a 3-ton residential system have come down about $900 and have captured about 8 percent of the space-conditioning market for new housing.

States and Utilities Lack Incentive to Implement Efficiency and Conservation Management Programs

Most utilities have little incentive to promote energy efficiency or conservation, especially when their profits are tied to the amount of electricity consumed. To change this situation, the Congress provided in the Energy Policy Act of 1992 that utility rate structures be as favorable for promoting energy efficiencies and conserving electricity as for investing in new power plant construction. The act requires state regulators to set utility rates that ensure comparable rates of return on their investments, thereby equalizing any income lost from lower revenue sales attributable to the utility's efficiency and conservation measures.

Many utilities operating below capacity feel neutral towards incentives to promote conservation and energy efficiency that will lower their companies' profits. Other utilities facing rising demand see more favorable results from investing in new power plants than in energy conservation measures. Nevertheless, the Energy Policy Act of 1992 authorized DOE to promote the development of technologies that would increase energy efficiency. The GHP is such a technology. In December 1993, a DOE official told us that DOE had done little to encourage state public utility commissions to implement efficiency and conservation measures—by, for example, promoting the use of GHPS—but that DOE was planning what its role should be.

Government and industry officials told us that utilities can play a pivotal role in expanding the markets for GHPS and other energy-efficient technologies. They believe that by actively promoting the technologies to their customers and by offering financial incentives—such as rebates—as well as cofunding design centers and demonstration projects, the utilities can influence customers to accept energy-saving technologies.

Some utilities have developed energy-saving incentive programs that include the promotion of geothermal heat pump installations. For example, as part of its program, the Pennsylvania Power and Light Company offers $1,000 rebates for installing GHPS. The program's goal is to have GHPS installed in 25 percent of new electrically heated homes by 1996.

DOE Has Provided Limited Support for GHP Technology

The low priority DOE has given to GHPS is reflected in the low budget it has allocated to activities supporting this technology. DOE's Office of Utility Technologies budgeted $250,000 in fiscal year 1993 for GHP activities and assigned one DOE headquarters staff member to work part-time on the program. A portion of the funds was used to cosponsor three teleconference panel discussions to inform utilities, builders, and

installers about the technology and promote it. According to a DOE official, none of DOE's national laboratories has focused on GHPs. Otherwise, aside from supporting the Geo-Heat Center in compiling and disseminating information on direct uses of geothermal heat, including GHPS, DOE has done little to support GHP technology. In its March 1994 response to a draft of this report, DOE stated that it had tasked the Sandia National Laboratory, in fiscal year 1994, with working on methods of reducing GHP installation costs.

The Energy Policy Act of 1992 included two provisions that could help DOE address some of the barriers to greater use of GHPs. These provisions authorized DOE to (1) conduct a 5-year program to promote energy-efficient heating and cooling technologies and (2) cofund the establishment of 10 regional demonstration centers to showcase the most efficient heating, cooling, and lighting technologies and provide information, training, and technical assistance to architects, designers, engineers, and contractors on energy-efficient technologies. While DOE officials have stated that the centers would serve a much-needed purpose, the 5-year program and the regional demonstration centers are not included in the Department's fiscal year 1994 budget.

Allocating funds within DOE entails policy decisions that frequently involve trade-offs among policy goals, including the need for budget restraint in light of continuing federal budget deficits. As we reported in 1992,[4] DOE's Office of Policy, Planning and Analysis, in preparing the Department's fiscal year 1993 budget request, concluded that DOE's program for energy-efficient buildings ranked higher in meeting National Energy Strategy goals than did most of DOE's other research programs.[5] However, DOE's fiscal year 1993 budget and resources remained geared to lower-ranked research programs in areas such as nuclear and coal technologies.

In commenting on a more recent GAO report,[6] DOE stated that when the new administration's management team arrived in January 1993, it reevaluated the funding for all renewable energy programs. DOE commented that in

[4]Energy R&D: DOE's Prioritization and Budgeting Process for Renewable Energy Research (GAO/RCED-92-155, Apr. 29, 1992).

[5]The National Energy Strategy, issued by DOE in 1991, had the following broad objectives: (1) improve energy supply and demand efficiency in a way that promotes economic efficiency, (2) reduce the adverse economic effects of oil supply disruptions, (3) strengthen the basic science research effort, including scientific education and technology transfer, and (4) enhance environmental quality.

[6]Electricity Supply: Efforts Under Way to Develop Solar and Wind Energy (GAO/RCED-93-118, Apr. 16, 1993).

future budget planning cycles it would give "priority consideration" to renewable energy programs and their counterparts. In January 1994, the DOE official responsible for GHP activities told us that although the budget for GHPs was not firm, he estimated that it would increase from $250,000 in fiscal year 1993 to about $400,000 in 1994. After receiving a draft of this report in February 1994, DOE's Acting Chief Financial Officer stated that the fiscal year 1995 budget request for GHPs was $2 million.

Conclusions

Only a small fraction of the U.S. market for heating and cooling is supplied by GHP technology—a technology that offers the potential for significant energy savings and environmental benefits. However, this potential will not be fully realized unless more information on the benefits of GHPs is disseminated to consumers, more system designers and installers are trained, greater efforts are made to lower installation costs, and more incentives are offered for utilities to promote the technology. The Department of Energy has the authority and responsibility to provide the leadership needed to overcome these barriers, but it has not exercised that leadership. The current administration's support for renewable energy and energy efficiency should provide the stimulus necessary for DOE to take the lead in promoting the use of GHPs.

Recommendation

Because of the significant economic and environmental benefits that geothermal heat pumps may provide, we recommend that the Secretary of Energy establish, under DOE's existing authority, a program to promote them as a tool for energy-efficient heating and cooling. Under this program the Secretary should

- gather and disseminate information on geothermal heat pumps so that utilities, contractors, and consumers will be aware of their benefits;
- establish, to the extent feasible, regional demonstration centers to provide information, training, and technical assistance to architects, designers, engineers, and contractors on geothermal heat pumps; and
- contact state regulators and utilities and encourage them to adopt conservation programs that will promote such energy-saving technologies as geothermal heat pumps.

State and Local Agencies, Utilities, Industries, and Organizations Contacted

State and Local Agencies

Alaska

Alaska Energy Authority

California

California Public Utilities Commission
California Energy Commission
City of Clear Lake
City of San Bernardino
City of Susanville
Imperial County Air Pollution Control District
Imperial County Health Department
Lake County Air Quality Management District
Lake County Resource Management Division
Northern Sonoma Air Pollution Control District

Nevada

Nevada Energy Office
Nevada Environmental Protection Agency
Nevada Office of the Consumer Advocate
Nevada Public Service Commission

Oregon

City of Klamath Falls
Northwest Power Planning Council
Oregon Department of Energy

Utility Companies

Atlantic Electric Company (N.J.)
Buckeye Power Company (Ohio)
Citizens Power and Light (Wash.)
Eugene Water and Electric Board (Oreg.)
Hawaiian Electric Company (Hawaii)
Idaho Power Company (Idaho)
Imperial Irrigation District (Cal.)
Los Angeles Department of Water and Power (Cal.)
Northern California Power Authority (Cal.)
PacifiCorp (Oreg.)
Pacific Gas and Electric (Cal.)
Pennsylvania Power and Light (Penn.)

Pennsylvania Rural Electric Association (Penn.)
Portland General Electric (Oreg.)
Public Service of Indiana (Ind.)
Puget Sound Power and Light (Wash.)
Sacramento Municipal Utility District (Cal.)
San Diego Gas and Electric Company (Cal.)
Sierra Pacific Power Company (Nev.)
Southern California Edison (Cal.)
Springfield Utility Board (Oreg.)

Industries, Energy-Related Companies, and Independent Power Producers

Ben Holt Company
California Energy Company
Calpine Corporation
Creston Financial Services
Energy Incorporated
Far West Capital
Foster Wheeler
Geolectric Power Company
GeothermEx
Magma Power Company
OESI
Oxbow Power Services
Pacific Energy
PRA Associates
S-Cubed
Supreme Resources
Trane Corporation
Trans-Pacific Geothermal
US Power Company
Waterfurnace
Yankee Caithness Joint Venture LP

National Organizations

Earth Energy Association
Edison Electric Institute
Electric Power Research Institute
The Electricity Council
Geothermal Resources Council/National Geothermal Association
International Ground Source Heat Pump Association
National Association of Regulatory Utility Commissioners

National Rural Electric Cooperative Association
Natural Resources Defense Council

Universities/Research Institutes

Massachusetts Institute of Technology, Energy Laboratory
Oregon Institute of Technology, Geo-Heat Center
Southern Methodist University, Department of Geological Sciences
Stanford University, Civil Engineering Department
University of Alaska Geophysical Institute
University of California-Berkeley, Department of Materials Science and Minerals Engineering
University of Hawaii Natural Energy Institute
University of Missouri at Rolla, Rock Mechanics and Explosives Research Center
University of Utah Research Institute

DOE's Program Opportunity Notice Projects

Dollars in millions

Project	Year completed	Cost share DOE	Cost share Others	Well Depth (ft)	Well Temp. (°F)
District heating					
Boise City, Idaho	1985	$3.63	$3.13	[a]	[b]
Elko, Nev.	1983	0.83	0.57	852	177
Klamath Falls, Oreg.	1983	1.27	0.79	367	218
Madison County, Idaho	Abandoned	0.80	0.09	3,932	72
Moana, Reno, Nev.	1982	0.94	0.03	900	250
Monroe, Utah	Abandoned	0.49	0.65	1,500	164
Pagosa Springs, Colo.	1986	1.21	0.27	[c]	[d]
Susanville, Cal.	1981	2.01	0.02	930	175
Institutional space heating					
Douglas High School, S.D.	Abandoned	0.03	0.16	3,679	[e]
El Centro, Cal.	Abandoned	2.30	0.07	[e]	[e]
Haakon School, S.D.	1982	0.94	0.27	4,266	153
Klamath County YMCA, Oreg.	1980	0.19	0.06	1,400	147
Navarro College, Tex.	1984	1.13	0.30	2,664	125
St Mary's Hospital S.D.	1981	0.55	0.19	2,176	108
THS Hospital, Tex.	1982	0.87	0.28	3,885	150
Utah State Prison, Utah	1986	0.49	0.33	1,000	180
Warm Springs State Hospital, Mont.	1983	0.72	0.04	1,498	154
Agribusiness					
Aqua Farms Int'l., Cal.	1981	0.36	0.00	[f]	[g]
Diamond Ring Ranch S.D.	1982	0.25	0.15	4,112	152
Kelly Hot Springs, Cal.	Abandoned	0.11	0.00	Spring	194
Utah Roses, Utah	1983	0.46	0.24	4,944	123
Industrial processing					
Holly Sugar, Brawley, Cal.	Abandoned	3.03	0.21	10,000	[e]
Ore-Ida Foods, Ontario, Oreg.	Abandoned	2.53	0.24	10,054	380
Total contribution		**$25.14**	**$8.09**		

(Table notes on next page)

[a]Well depths ranged from 800-2,010 ft. for four wells.

[b]Temperatures ranged from 155-172^{0} F.

[c]Well depths ranged from 275-300 ft. for three wells; one well was abandoned.

[d]Temperatures ranged from 131-148^{0}F.

[e]Not applicable

[f]Well depths ranged from 140-800 ft. for 7 wells.

[g]Temperatures ranged from 79-107^{0} F.

DOE's Program Opportunity Notice Projects Abandoned or Terminated

Dollars in millions

Project	DOE	Others	Comment
Abandoned project			
Douglas High School, S.D.	$0.03	$0.16	Drilling problems
El Centro, Cal.	2.30	0.07	Inadequate resource
Holly Sugar, Brawley, Cal.	3.03	0.21	Inadequate resource
Kelly Hot Springs, Cal.	0.11	0.00	Inadequate resource
Madison County, Idaho	0.80	0.09	Inadequate resource
Monroe City, Utah	0.49	0.65	Inadequate resource
Ore-Ida Foods, Ontario, Oreg.	2.53	0.24	Inadequate resource
Total contribution	**$9.29**	**$1.42**	
Terminated project			
Diamond Ring Ranch, S.D.	$0.25	$0.15	Equipment failure
Navarro College, Tex.	1.13	0.30	High operating expenses
THS Hospital, Tex.	0.87	0.28	Hospital closed
Utah State Prison, Utah	0.49	0.33	Lack of personnel support
Warm Springs State Hospital, Mont.	0.72	0.04	Equipment failure
Total contribution	**$3.46**	**$1.10**	

Comments From the Department of Energy

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Department of Energy
Washington, DC 20585

March 16, 1994

Mr. Victor S. Rezendes
Director, Energy and Science Issues
Resources, Community, and
Economic Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Rezendes:

The Department of Energy appreciates the opportunity to review and comment on the General Accounting Office draft report GAO/RCED-94-84 titled "Geothermal Energy: Outlook Limited for Some Uses but Promising for Ground Source Heat Pumps."

See comment 1.

We are disappointed by the pessimistic tone of this report, especially regarding the generation of electric power from geothermal resources and by the manner in which the authors support some of their conclusions. Although the authors should have a wealth of data from interviews with many geothermal stakeholders, the comments selected for use in the report, often with little or no evaluation, are predominantly those that bolster a particular conclusion. Other relevant material is omitted. Our specific comments are as follows.

See comment 2.

First, the title of the draft report gives a negative impression that is not supported by the documentation within. We suggest a neutral title: "Geothermal Energy: Outlook for Near-Term Utilization."

See comment 3.

See comment 4.

Second, the draft report suggests that independent projections of substantial geothermal contributions to near-term electric power needs in the western U.S. are overly optimistic. Most of these estimates have assumed increased levels of research and development expenditures. The draft report recognizes that the cost of geothermal power is highly technology-dependent and that previous Department of Energy research has been effective in reducing that cost. Despite this evidence, the draft report appears to assume that geothermal technology will not improve, present and future research and development will not lower geothermal costs, and geothermal's historical trend toward lower prices will not continue.

See comment 5.

We would argue that the General Accounting Office analysis is unduly pessimistic in this regard. Our view is supported by recent developments in southern California, for example, with commitments for over 400 megawatts of new geothermal power. The Los Angeles Department of Water and Power is developing 240 megawatts of geothermal power at the Coso resource for its own use, and Magma Power Company has received purchase agreements for 170 megawatts of geothermal power from Southern California Edison and San Diego Gas & Electric. The draft report, however, cites both utilities as

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unenthusiastic about future geothermal prospects. There are, of course, many other commercial geothermal development projects planned or under way in California, Nevada, and Oregon. These individual advances are consistent with, and representative of, the overall trend of western utilities' commitments to geothermal energy as an element of their supply mix.

See comment 6.

Third, the draft report fails to note the recent great success of the U.S. geothermal industry in introducing its superior world class technology into international markets. U.S. firms have recently received commitments from foreign nations for the development of thousands of megawatts in this decade. These projects, in Canada, the Philippines, Indonesia, and central America, involve Union Geothermal, Magma Power, California Energy Company, Geothermal Power Company, Trans-Pacific Geothermal, Ormat Energy Systems, and others. Past accomplishments of the Department of Energy's geothermal research and development program are in no small part responsible for these advances.

See comment 7.

The Energy Policy Act of 1992 contains numerous provisions for bringing renewable energy technologies, including geothermal, to a state of competitiveness in domestic and foreign markets. The draft report mentions this critical legislation but does not appear to take into account its potential impact on geothermal energy's contribution to future power markets.

See comment 8.

The President's Global Climate Change Initiative seeks to accelerate the rate at which increased energy efficiency and renewable energy resources displace conventional energy sources that generate greenhouse gases, domestically and around the world. This action supports an increased rate of research and development for most of the renewable energy sources, including geothermal energy. Some of the geothermal increase is aimed at programs through which the Department of Energy and the heat pump industry will hasten the spread of geothermal heat pump technology in all parts of the U.S. The balance will be used in close cooperation with the geothermal industry for projects that will reveal previously undiscovered geothermal resources, reduce development and plant costs, and make geothermal energy even more environmentally attractive. It should be noted here also that revenues from geothermal leases on Federal land currently exceed the congressional appropriation for geothermal research.

See comment 9.

Finally, comments in the draft report related to the longevity and productivity of geothermal reservoirs are excessively pessimistic. In particular, the author of the draft report misses the significance of recent events at The Geysers geothermal reservoir. It was the first geothermal reservoir to be developed in the U.S. and has served as a prototype. Over a period of 35 years, many wells were drilled there, many plants were built, and many lessons learned. By the mid-1980s, The Geysers was supplying some 2000 Megawatts to the electric grid. Then steam pressures began dropping and production fell off. The Department of Energy and the geothermal industry quickly instituted a cooperative research and development program to evaluate the causes and suggest remedies. The results of that program show that the reservoir is running low on fluid, but that it still contains over 95 percent of the original heat in place. Producers had been injecting very little of the produced fluid, letting most of it evaporate into the atmosphere. The research and development program also showed that it is possible to greatly

reduce the power decline of The Geysers, and by modifying the power plant design, injecting most of the produced fluid, and adding fluid from one or more external sources, the reservoir can supply at least several hundred megawatts for another 50 years.

See comment 1.

Geothermal technology is in its infancy and much remains to be learned and applied. However, recent lessons learned at The Geysers and the cumulative results of nearly two decades of research and development have been (and are being) applied by the U.S. geothermal industry, yielding impressive results at home and abroad. With sustained improvement, the future of geothermal energy is bright. All of this evidence supports the conclusion that geothermal electric power, as well as geothermal heat pumps, can and will contribute substantially to the Nation's energy future.

See comment 10.

Some suggestions of an editorial nature have been provided to the General Accounting Office under separate cover. The Department hopes that the comments in both letters will be helpful in the preparation of the final report.

Sincerely,

Elizabeth E. Smedley

Elizabeth E. Smedley
Acting Chief Financial Officer

The following are GAO's comments on the Department of Energy's letter dated March 16, 1994.

GAO Comments

1. Our conclusion that the outlook for geothermal generation is limited is based on numerous factors discussed in the report, including (1) the absence of major new geothermal fields, (2) the decline of production from existing fields, and (3) market factors that currently make fossil fuel more attractive as an energy source. As described in the objectives, scope, and methodology section of chapter 1, we obtained information and solicited views from a large number of federal and state government officials, utility companies, and geothermal industry specialists. This information was carefully analyzed by our evaluation team. Furthermore, DOE's technical comments to the report do not raise any concerns or provide any corrections or additions to the projections contained in the report.

DOE's data and projections for geothermal power further support our conclusion. DOE reported that geothermal generation nationwide accounted for 2,700 megawatts in 1990 and 2,100 megawatts in 1993. Recently, in support of its fiscal year 1995 budget request, DOE projected 4,000 megawatts by 2000. While at first glance this potential increase may look significant, geothermal energy today provides less than 1 percent of the nation's generating capacity, and it will still provide less than 1 percent in 2000.

2. We disagree. The report's title is supported by the preponderance of evidence we obtained during our review. It describes the limited potential for significantly increasing geothermal generating and direct-use applications while drawing attention to the promising potential for geothermal heat pumps. In addition, DOE has not provided any updated information that would necessitate a change.

3. We disagree that most of the projections discussed in chapter 2 were based on increased levels of research and development expenditures. DOE officials raised this point when we met with them to verify the factual material in the report. At that time, we discussed the documentation supporting the studies cited in our draft report and told DOE that the studies did not assume a significant increase in research and development expenditures. DOE officials acknowledged that DOE's projections may not be realized because funding for research and development has been lower than anticipated.

4. We disagree with DOE's statement that the draft assumes that the technology will not improve, that research and development will not lower costs, and that the historical trend toward lower prices will not continue. Chapter 2 details some of the research and development projects that geothermal companies say may help reduce the cost of geothermal electricity production. The chapter also states that many of these companies believe that this cost reduction will make them more competitive with other power sources.

5. We do not believe that our analysis of the potential for electricity generation from geothermal resources is unduly pessimistic. Utility companies reported to us that they project a total of about 530 megawatts of new geothermal power production by the year 2000. This includes 170 megawatts by Southern California Edison and San Diego Gas and Electric; however, Los Angeles Power and Electric reported to us that they have downsized their plans for geothermal development. In addition, DOE recently downsized its projections for geothermal power by the year 2000. In the March 10, 1994, hearing before the Subcommittee on Energy and Water, House Committee on Appropriations, the Assistant Secretary, Energy Efficiency and Renewable Energy, testified that by the year 2000 geothermal power would be 4,000 megawatts, whereas DOE's Annual Energy Outlook 1993 projected 5,180 megawatts by the year 2000. This new estimate represents a 23-percent reduction from the earlier projection.

6. The objectives of this audit did not include evaluating the progress of geothermal development in international markets.

7. While we cite specific provisions of the Energy Policy Act that apply to geothermal energy, the scope of our audit did not include an evaluation of how the act's provisions would influence geothermal energy's contribution to future power markets.

8. It was beyond the scope of our review to analyze the President's Global Climate Change Initiative, which, according to DOE, seeks to accelerate the rate at which energy-efficiency measures and renewable energy resources displace conventional energy sources that generate greenhouse gases. However, we did point out that the environmental problems associated with geothermal power production are fewer and less serious that those associated with fossil fuels. In addition, we support increased DOE activity in conjunction with private industry that will hasten the spread of geothermal heat pumps.

9. We disagree that our discussion of the longevity and productivity of The Geysers is excessively pessimistic. As discussed in chapter 2, operators at The Geysers told us that the capacity is expected to decline by about 50 percent over the next 20 years, from 1,220 megawatts in 1993 to about 600 megawatts.

10. In a separate addendum, DOE provided editorial comments that we have incorporated where appropriate.

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